RECOVERY WORK
AFTER PIT FIRES

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A DESCRIPTION OF THE PRINCIPAL METHODS PURSUED ESPECIALLY IN FIERY MINES; AND OF THE VARIOUS APPLIANCES EMPLOYED, SUCH AS RESPIRATORY AND RESCUE-APPARATUS, DAMS, ETC.

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TRANSLATED FROM THE GERMAN BY CHARLES SALTER

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PREFACE.

THE present work deals, in the most concise manner possible, with the actual state of knowledge in relation to recovery work after pit fires. The literature of the subject does not contain much that can serve for the guidance of the practical man, and the present is the sole existing work treating exclusively of this branch of the miner's art in its actual state of development.

The author was encouraged to publish this volume by reason of his long experience in various mines and extensive travels abroad. It will be found to commence with dissertations on the origin, indications and means of preventing pit fires, followed by a description of all the best methods of effecting the subsequent recovery work. The examples cited of actual instances in practice, stripped of all superfluous matter, should facilitate the better understanding of same, and better enable the practical man to adopt the most suitable measures in face of an actual catastrophe. Even though the conditions vary in cases of accident, the expert will be able to utilise the experience detailed in these descriptions, partly in taking measures for preventing future disasters,

partly in sorting out proved measures and rejecting such as are unsuitable.

In the case of pit fires, as in war, every possible expenditure of physical and mental power must be devoted to the task of saving life and property. Sometimes the end is only attainable after great trouble and careful labour, whilst at others a single act rapidly carried out has most important results. One can imagine the responsible position of a mine manager confronted, at the outbreak of a catastrophe, with the problem whether to increase the speed of the ventilating machinery or to stop it altogether, the lives of many hundreds probably resting on his decision. The only way to success in recovery and rescue work is by adopting a suitable and systematic method based on the results of practical experience. That the present work may, if only to a limited degree, contribute to the solution of this most difficult of all tasks in mining, is the sincere hope of

THE AUTHOR.

KLADNO, AUSTRIA.

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I. CAUSES OF PIT FIRES.

FIRES in collieries may arise from three causes:—

1. Spontaneous ignition of the coal.
2. Outbreak of fire in the timbering.
3. Explosions of fire-damp.

1. FIRES RESULTING FROM THE SPONTANEOUS IGNITION OF COAL.

This, the most frequent source of pit fires, is liable to occur when small coal is left behind in the workings, or when, in consequence of defective management, the residual coal pillars are crumbled by the pressure to which they are exposed, the result of which is that, in the cracks and corners of the pillars, an accumulation of coal dust ensues and spontaneous ignition follows. From the standpoint of national economy such methods of coal winning that allow a portion of the roof coal to be left behind must be regarded as wasteful in the extreme. When the coal begins to fall quickly and irregularly, the miner naturally does not care to risk his life in drawing it away. Consequently a large proportion must be left behind in the goaf, the result of which is that the broken coal subsequently ignites, this condition ensuing all the earlier when the coal becomes mixed with the cover rock, which is frequently bituminous and endowed with a tendency to

ignition. Thick seams are more particularly exposed to spontaneous combustion, the goaf being more especially liable to take fire with great readiness. The only way of preventing this danger in thick seams is by thoroughly packing the goaf with uninflammable material, which, if necessary must be brought into the mine from outside sources.

According to Muck, absorption of oxygen is the prime factor causing the spontaneous ignition of coal, *i.e.*, a rapid oxidation (weathering) resulting in the formation of carbon dioxide and water—the decomposition of pyrites being of merely secondary importance in this connection. The latter phenomenon, which only occurs when moisture is present, is accompanied by a disengagement of heat which to some extent facilitates the oxygen absorption.

Moisture alone has no influence on the weathering of coal. At the outset small coal absorbs oxygen at a more rapid rate than lump coal, and consequently the former will usually heat spontaneously to a greater extent and weather more quickly than the latter.

According to Busse, the tendency of coal to weather is in the first place induced by the oxidation of hydrogen, then by the oxidation of carbon, and finally by the absorption of oxygen (up to 4 per cent.). As this tendency increases in proportion to the area of surface exposed to the air, it would appear to depend inversely on the size of the lumps and the porosity of the material—dense lump coal weathering less easily than coal dust.

The presence of iron pyrites, though frequently assumed to play no important part in the origin of pit fires, nevertheless favours spontaneous heating in coal, especially where moisture gains access. In contact with air and moisture, pyrites suffers decomposition and is converted into ferrous sulphate (green vitriol), the chemical reaction being attended by a liberation of heat, which, under certain circumstances, may

set the coal on fire. Pyrites is a frequent cause of spontaneous ignition in coal stores and in packing goaf. It is an ore that rarely occurs in large masses, but is more usually distributed through the coal in the form of fine scales, or as crystals in shale and kidney-shaped masses of ironstone; though at rarer intervals it is met with in the condition of continuous thin strata embedded in coal seams. Where pyrites is abundant in coal, care should be taken to raise it from the pit and separate it from the coal by picking. When the coal is treated by the aid of washing plant, the latter forms an excellent means of freeing it from pyrites.

The picked or washed-out pyrites can be disposed of to the sulphuric acid manufacturer when present in sufficient quantity, thus obviating the danger attending its use as a packing material, whilst at the same time the quality of the coal is improved and an additional source of revenue established. Again, the presence of pyrites renders coal unsuitable for metallurgical purposes.

The most instructive examples of the causes of pit fires are afforded by the conflagrations in the mines of Southern Hungary, originating, as they have been found to do, in a multiplicity of causes, such as: methods of working whereby small coal is left behind in the mine; heavy rock pressure; spontaneous heating of the packing material; unequal moisture in the coal measures; leaving behind large quantities of timber in the old workings, etc.

In 1857, a fire originating in a residual coal pillar broke out at the Breuner shaft, the main seam of which, about 13 feet thick, extended for a distance of 65 yards by 550 yards.

The pit had in consequence to be abandoned, and continued to burn for several decades; and it was only after a prolonged and laborious task of dumping loam and sand down the shaft that the flames and smoke could be suppressed. As, however, in the winter of 1897-98, the mine

had cooled down sufficiently to allow the snow to lie unmelted round the upcast, the working will probably be resumed ere long.

Proof of the causative influence of rock pressure on pit fires is afforded by the outbreak in the main seam at the Gustav shaft, the western boundary of which seam is formed by an extensive fault. In consequence of this fault the Thinnfeld main seam with the whole of the cover rock has been thrust over the Gustav seam and exerts an enormous pressure upon the latter. Furthermore, the coal in these seams is very easy working, whereas in other fields it has to be got by blasting. Now from the second level of the Gustav shaft—which level is 270 feet below bank and was begun in 1846—down to the ninth, which is at a depth of 1,443 feet, pit fires have been of frequent occurrence on each level, and in the vicinity of the said fault, so that the average during the last fifty years has been one fire every two years in this one set of workings alone.

Moreover, owing to the somewhat steep pitch of the seams—the average angle being 50°—the great pressure of the cover rock over the goaf causes the heat to be for the most part retained, its escape in an upward direction being prevented.

According to the experience gained in Upper Silesia the presence of compact rock, affording an impenetrable cover after subsidence, favours the occurrence of pit fires. On the other hand, the spread of such fires—when once started—is more facilitated by the presence of a permeable cover rock which permits access of air from above ground. For this reason all fissures detected in the rock, in surface subsidences, etc., should be packed and stopped, and no small coal should be left behind in the workings.

The heat developed in the materials used for packing the goaf, also greatly favours the occurrence of pit fires. For

instance, in former years the packing used at the Anina pits consisted almost exclusively of the sandy to slaty rock and gassy clay shale overlying the coal-bearing sandstone strata. This clay shale was won by driving transverse cuttings into the shale and allowing the roof to fall—a method not only dangerous to human life by direct accident from the falling material, but also leading to the formation of spaces where fire-damp could accumulate and whence it could be driven into the workings by the concussion due to further subsidences. From this cause an explosion, resulting in the death of two men and severe injury to seven others by burning, occurred in the Thinnfeld pit on 24th December, 1870, although the miners were provided with Heinbach safety lamps. The clay shale—which at that time constituted, in conjunction with the sandstone taken from cross drivages, about 50 per cent. of the total packing, the remainder being marl obtained from above bank—heated spontaneously to such an extent that the temperature in the workings rose to an average of 100° F., and even at present cannot be reduced below 86° F., owing to the difficulty of excluding the aforesaid shale from the packing; in fact it seldom falls lower than 95° F. As the working stages advance gradually from the lower to the upper sole, the temperature rises as the amount of packing increases; and therefore, to prevent this as far as possible, it has for several years been the custom to divide the working section by two or three horizontal cuttings instead of leaving it all in one block extending from one sole to the next higher one—a superficial height of 65-70 yards. By this means the advantage is obtained that in case of an outbreak of fire the area to be isolated is small.

The use of waste rock from the headings is strictly prohibited for packing, as, in despite of penalties, it is only with great difficulty that the same can be kept free from the accompanying coal and shale.

Another predisposing cause of pit fires is *the employment of old mine timbers in packing.* The miners are readily inclined to this misuse, because it is very often difficult to convey the old timbers through the sloping drifts into the headings and up to bank, whilst on the other hand, they earn more money by secretly placing the timbers in such a manner as to leave hollow spaces and thus save the troublesome task of packing. Now, these spaces are soon logged with pit water, and also form dangerous centres for the accumulation of fire-damp. Furthermore, the air and moisture traversing the hollows also facilitate the weathering of the coal and the decomposition of pyrites.

Still another condition favouring outbreaks of fire is the leaving behind in the goaf of timber, rendered necessary by the method of working pursued, and which cannot be recovered without danger to life and limb. Experience shows that fires in the pit and waste heaps are usually generated and extend in and along the timbers enclosed in the coal or débris, possibly by reason of the accumulations of air and moisture between the wood and the coal, rock, etc. The careful stopping-up of old workings is a necessary task, though it forms no absolutely certain precaution against pit fires.

The spontaneous ignition of coal is likewise facilitated by the slight current of air continually passing through the goaf, principally through abandoned headings—be they never so tightly packed. Air also gains access through the fissures quickly produced in safety pillars by the enormous pressure of the cover rock. Goaf fires of the worst type are generally produced when a considerable quantity of fine coal has been left behind among the packing material, and the ventilating current is insufficiently strong to keep the mass cool, though enough to support gradual combustion.

With regard to the influence of moisture, it has been found

in Anina that a *little moisture*—not decided wetness—contributes to the generation of pit fires, such fires having been repeatedly found to occur in the course of a few weeks after the water in the workings has been drained off in another direction, and the degree of moisture thereby reduced to a low figure.

2. Fires Caused by Burning Timber.

On 31st May, 1892, a fire causing a sacrifice of 319 lives, was produced in a pit at Pribram (Bohemia) through the ignition of timbering in consequence of the careless handling of an open lamp; and the same cause led to the loss of 101 miners out of a total staff of 144, at the Cleophas pit near Kattowitz (Silesia). In the Anina district such fires were of frequent occurrence prior to the universal adoption of the safety lamp in 1885. In one of these fires (at the Kübeck shaft, 11th December, 1884) forty-eight lives were lost, in consequence of the spread of the after-damp—mainly composed of the murderous gases carbon monoxide and carbon dioxide—into the workings along with the ventilating current. Again, the shaft fire at the Zollern pit (Westphalia), where forty-six lives were sacrificed through the ignition of a rope by an open lamp, will be still in remembrance. The careless handling of open lamps among fodder stored in underground stables is also a frequent cause of fire; and carelessness in stoking a ventilating fire or a boiler fire underground may equally lead to a conflagration.

With regard to fires caused by *steam pipes*, it is found that though these pipes are never hot enough to actually ignite adjoining timbers, these latter may, however, be gradually charred so that the surface of contact exposed to the air is considerably increased. The resulting loose mass then greedily absorbs oxygen, especially during cooling, and this may go on to such an extent as to produce ignition.

In consequence of the *short circuiting of an electrical cable*, a fire, resulting in a loss of sixteen lives, was started at the Herminegild shaft (Poln.-Ostrau) on 14th January, 1896. The cause was traced to a breakage of wire in the otherwise sound electric cable in the shaft—a circumstance which had hitherto received very little attention, and one regarded by the local experts as impossible of occurrence.

3. Fires caused by Fire-damp Explosions.

Numerous fires have resulted, in fiery mines, from the explosion of fire-damp or coal dust, due either to carelessness in the use of naked lights (*e.g.*, smoking, opening the lamps, flaring), or by accidents in blasting, such as a blown-out shot or a spark from the igniter in firing the charge. In such case, the extra ventilation frequently necessary for ensuring the rescue of the men supplies an additional volume of fresh air to the still uncooled seat of the explosion and gives rise to fires, the flames of which may in turn ignite accumulations of fire-damp, especially that streaming into the workings from the goaf. When the ventilation is arrested and the site of the fire is isolated, there ensue repeated explosions due to the formation of explosive mixtures of air and fresh gas escaping from the coal, until the available oxygen is for the most part consumed and has become insufficient to constitute such mixtures. The fire, however, will continue to rage in proportion as it receives an accession of oxygen whether in consequence of the defective performance of recovery work or of imperfect damming—the wood work, or any faggots in the packing, and even the coal forming centres of combustion.

An accident in firing a blasting charge caused the explosion and subsequent fire at Karwin (Silesia) on 14th June, 1894, in which the fatalities numbered 223; and also the explosion and pit fire at Anina on 24th October, 1894,

where forty-eight were killed and a large number severely injured from burns. The flaring of a miner's lamp produced the fire-damp explosion at Reschitza (Hungary) on 23rd November, 1896 (eighty-two deaths), where the shaft, at a distance of over 1,300 yards from the seat of the explosion, was destroyed by fire.

II. PREVENTIVE REGULATIONS.

The *precautions against the dangers of shaft fires* have been divided by Mining Councillor J. Mayer (in a paper on the conflagration at the Zollern pit)[1] into the following classes:—

1. Precautions for preventing the occurrence, or retarding the rapid extension, of such fires.

2. Precautions to be adopted, when a fire has broken out, in order to quickly localise the conflagration and isolate it from the rest of the workings.

3. Precautions that must be resorted to when those described above prove inefficacious.

1. The Outbreak and Rapid Extension of a Shaft Fire can be Most Reliably Prevented by Employing Little or No Combustible Material in the Construction of the Shaft.

The intake air shaft should, therefore, be lined with masonry, concrete, or similar material, and the necessary internal fittings made of iron. Naturally, iron-lined shafts, wherein wooden posts—which may be hard or soft wood impregnated or unimpregnated—are sometimes largely employed, cannot be regarded as fireproof. This was conclusively shown by the fire in 1896 at the Herminegild shaft which was of this class. Hence, when iron is used for lining the shaft, the headings and haulage ways must also be made fireproof, or lined with iron, which lining must extend

[1] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1898. No. 35.

from the loading places at least as far as the nearest air doors in the adjacent cross drivages. It is also advisable to construct these doors of iron, in order to prevent the spread of fire into the cross drivages.

Such fireproof lining of intake air shafts, which generally also serve as winding shafts, is an economic necessity, and consequently, new installations of any size are nowadays almost exclusively fitted on this plan. It also frequently happens that in reconstructing timbered shafts a fireproof lining is provided.

Nevertheless, there still remain a number of combined winding and ventilating shafts lined with timber; and indeed it is a difficult matter to entirely exclude combustible materials from the shaft, many such materials—such as timbering, fodder and straw for the horses employed in the pit, all kinds of cleaning waste and lubricants for the underground machinery, etc.—being necessarily lowered through such shafts and stored, even though only as a temporary measure, in the loading places or shaft buildings at the pit mouth.

The fireproof fitting of the shaft must also be extended to the adjacent buildings, etc., at the pit mouth, since a fire there would be attended with as great danger, if not greater, to the working staff, owing to the risk of affecting the entire ingoing ventilating current, whereas in the case of a mere shaft fire, some of the divided air currents could, under certain circumstances, be maintained intact. The whole of the buildings should therefore be made fire proof and insulated by means of fireproof walls or quick-closing iron doors, etc.

Shafts lined partly or throughout with timber are particularly liable to take fire if dry; and, when they contain steam pipes, the latter thoroughly dry any adjacent, imperfectly insulated timber and thus render it especially liable to burn. To prevent this desiccation, which moreover shortens the life of the timber, the whole of the wooden lining and

fittings must be regularly and thoroughly moistened, an object best effected by sprinkling from a system of perforated water pipes arranged all round the shaft. Where the shaft contains a passage way for the miners, the sprinkling must be suspended for a short time before the way is used. The steam pipes in the shaft must be protected from contact with the sprinkling water by means of sheet metal covers.

A principal factor in the prevention of shaft fires is the *mode of lighting selected and the proper supervision of same.*

Testimony in favour of the necessity of the universal adoption of closed lamps for miners' use, is afforded in the following terms by H. Guttmann who for many years had the management of fiery lignite mines in North-West Bohemia and in Styria. He says: "What mining official has not reflected on the danger of open lamps in the hands of unintelligent miners especially in traversing well-ventilated, dry galleries plentifully lined with wood timbering? How often do we find, in haulage ways or working places, still-glowing particles of wick, which only require a single factor—only absent by accident—to become the cause of a pit fire! How often do we find lamps hung, through negligence or for convenience, on the timbers in the working places, in such a manner as to char the wood! Many pit fires of untraced origin must have been produced by the careless handling of open lamps.

"Although the great danger of the naked light—especially in dry coal pits, and attaining its maximum where a large quantity of timbering is necessary—can be partly lessened by instructing the men and by strict supervision, it can never be entirely obviated; and consequently one is not only justified in advocating the abolition of open lamps, but even bound to do so."

The task of converting an open oil lamp into a kind of lantern, and imparting to it the character of an oil safety lamp,

is by no means practically easy, owing to the poor light obtained after this conversion. The oil flame smokes, dirtying the glass and stopping up the air holes, etc., so that the illuminating power of the lamp is low. This circumstance accounts for the fact that it was only after the occurrence of many great accidents, and, for the most part, in consequence of official intervention, that the ordinary oil safety lamp gradually came into use.

A further drawback of the lantern form of this safety lamp is the broad conical shadow which is cast by the large oil container and prevents the proper examination of the sole.

The first-named defect is easily overcome by abolishing oil and employing benzine in the lamp; and since the Wolf benzine lamp has come into general use it is found that this mineral oil burns with a uniform flame and gives at least 40 per cent. more light than rape oil, without the wick requiring to be raised or the oil itself giving off smoke. It has also been proved to cost only one third as much as rape oil. Moreover, owing to the smaller space required for the benzine, the unwelcome shadow cast by the container can be considerably reduced. For these reasons, therefore, we must confine our attention to the benzine lamp, which, for use as a closed lamp for pits that are free from fire-damp, should be constructed on the following principles:—

1. The general outline of the existing form of safety lamp should be retained as being the most durable and handiest.

2. The lamp should be fed with benzine in order to combine good illuminating power with cheapness.

3. When intended for use in non-fiery mines the construction of the lamp can be simplified, thus giving higher illuminating power than the present Wolf benzine lamp.

4. The weight can at the same time be reduced to 1¾ lb.

5. By making the container of conical shape and using

transparent material for the bottom on which it rests, the conical shadow can be reduced to minimum dimensions.

6. The provision of a locking device which cannot possibly be opened by the miner alone is indispensable.

7. When an igniter can be attached to the lamp without reducing its lighting power, this should be done.

After the aforesaid timber fire in 1884 the whole of the coal pits at Anina, even those classed as "non-fiery," were provided with the Müseler safety oil-lamp, which was afterwards replaced by the Wolf benzine safety lamp. Since that time there has been no recurrence of fires through the ignition of timbering. The saving effected in the change from the Müseler lamp to the benzine lamp in the whole of the South Hungarian collieries, employing a total of 5,000 men, was estimated in 1896 at 25,000 florins (over £2,000). This may be accounted for to some extent by the circumstance that some of the men used to steal the oil, but ceased to practise this theft on the introduction of benzine. In dangerous fiery mines the loading places have necessarily to be lighted with safety lamps alone, in view of the possible dangers from fire-damp and coal dust; but in mines less infested with fire-damp, and in all others, open lights are permissible.

It must not, however, be understood that the term "open lights" used in the Fire-damp Regulations invariably means an open lamp flame as opposed to safety-lamp illumination. In particular the use of open flame lamps is impermissible in shafts liable to fire risks, especially where all kinds of combustible materials, such as hay and straw for the pit horses, even when—as ordinary care necessitates—they are enclosed in less inflammable covers, such as sacking, etc.

Thus, even where open lights are permitted, they must in many instances be protected externally, *i.e.*, a kind of lantern or other enclosed lamp must be used; for example, in underground stables, in storehouses for inflammable materials, in

timbered parts of the mine where the wood is dry and in many cases splintered by the heavy pressure of the cover rock. In many pits where open lights are allowed, the loading places are preferably lighted with large safety lamps, *i.e.*, powerful lamps constructed on the lines of the safety lamp, the flame being protected by a glass chimney and a wire-gauze cylinder. It is also advisable to set up in loading places electric safety lamps, since these can always be maintained in good working order and may do good service, at all events at the most critical moment, in case of the sudden extinction of all the other lamps.

Telephonic communication between connected shafts and from thence to the manager's office is of great value. It may be mentioned that in the case of the shaft fire at Reschitza, already alluded to, in 1896, the telephone wire leading from the manager's office to the shaft, *via* the main drift, was destroyed by the force of the explosion, and that, in consequence, the delayed rescue work was unsuccessful.

A sufficient number of *hydrants* for the rapid extinction of an outbreak of fire should be provided in the buildings at the pit mouth. Great value also attaches to the provision of a few *signalling appliances* that can be readily manipulated from the cage at any part of the shaft, since in the case of rescue work—whether with or without respiratory apparatus—it is very useful to be able to communicate rapidly and with certainty between the pit mouth and the rescue parties.

With regard to reliable signalling appliances it may be mentioned that Siemens and Halske of Berlin have developed a system based on railway signalling apparatus. The use of magnetic induction apparatus plays a considerable part in this system, the reliable action of these sources of current being unapproachable by batteries. Nevertheless cases arise in mines where batteries alone are suitable, *e.g.*, when it is a matter of signalling from selected points.

A small induction apparatus for pit work is shown in Plate V., Fig. 1. A Siemens double-T armature, enclosed by the poles of a number of powerful steel horseshoe magnets, is coupled, by means of ratchet and pawl gear, to a crank in such a manner that the armature is set in motion only when the crank is turned to the right, but remains at rest if the crank is moved in the opposite direction. By this means, and by the provision, on the back plate, of lugs against which the crank handle strikes on being moved backwards and forwards, it becomes possible to transmit well defined signals.

The *electric bell signal*, or alarm (Plate V., Fig. 2), which receives and is actuated by the alternating currents generated in the induction apparatus, consists principally of an electro-magnet, over the poles of which is freely suspended a soft iron armature influenced by a permanent steel magnet. This armature carries a hammer which, under the influence of the alternating current traversing the bobbins of the electro-magnet, strikes alternately on the two powerful bells mounted on the base plate.

For communication between stations the telephone is used. A *pit telephone*, such as shown in Plate V., Fig. 3, is employed in conjunction with the signalling appliances, and is usually provided with a microphone attachment for increasing sound and rendering the messages more clearly audible.

To protect apparatus of this kind from damage by shock and from the injurious influence of the pit atmosphere and moisture they should all be enclosed in strong, water-tight metallic cases. Suitable conducting cables for pit use are employed to connect the above-mentioned parts of the various signalling devices.

In order to test the suitability of the pit air for respiration, ordinary lighted lamps are mounted in the cages. They do not, however, afford any accurate criterion in the case

of air impregnated with carbon monoxide, as was proved at the Herminegild shaft fire, where a safety lamp was found burning in one of the stalls near the body of an asphyxiated horse.

With regard to the appointment of rescue stations above and below ground, with their appurtenances, such as respiratory apparatus, electric safety lamps, axes, hammers, nails, stretchers, etc., this matter will be dealt with in Chapter VI.

2. Precautions for Rapidly Localising an Outbreak of Fire in the Shaft.

Here a distinction may be drawn between fires in the buildings and gear at the pit mouth and those occurring within the shaft itself. With regard to the former case, the most important step to be taken is *the closing of the intake ventilating shaft by suitable iron flap doors on the kerb*—the air supply and other communication with the intake shaft being effected through a special brick-lined conduit or gallery placed below the mouth of the pit and debouching some distance from the shaft at a situation protected from fire. In the Ostrau-Karwin district the provision of such a conduit and the necessary appurtenances is prescribed for all coal pits, by the Mining Police Regulations. In the case, however, of an outbreak of fire in the intake ventilating shaft itself, these precautions are insufficient, and may, indeed, become a source of danger. When such an outbreak occurs *the air supply must be cut off in the intake levels nearest the loading places.* The aforesaid Mining Police Regulations for the Ostrau-Karwin district deal with this contingency as follows: "In the case of pits provided with *several* intake ventilating shafts, doors must be erected in all levels opening into any shaft liable to be endangered by fire. These doors,

usually left open, must be closed in case of a shaft fire in order to isolate the shaft from the workings, the ventilation being effected through the other intakes that still remain intact. In pits with only a *single* intake air shaft the ventilator must be stopped and endeavours made to produce an up draught in the burning shaft and reverse the entire ventilating current throughout the pit." Mayer recommends the provision of reserve doors for the intake levels in all cases, in order to ensure the safety of the endangered miners and of the pit.

The object of such reserve doors near the loading places on the different levels is to prevent the flow of contaminated and smoke-laden air from a burning shaft into the workings. The stoppage of the ventilating fan is not sufficient to effect this at once, because, as a rule, the air ascending the upcast ventilating shafts is warmer than the incoming air, and consequently the natural circulation is still maintained after the fan has been stopped—the result being the conveyance of smoke fumes into the workings. In addition, the reserve doors are intended to keep the smoke above ground in case of a fire in the buildings at the pit mouth, particularly when the shaft cannot be closed in time by the flaps on the curb, or when these appliances get out of order.

The task of looking after all these reserve doors in the various levels is entrusted to the setters-on employed at the loading places. As a rule, the number of air intake levels is few ; in many cases only one, which serves at the same time as the main haulage way and is always occupied by loaders during working hours. These men, in the event of an inrush of smoke fumes to the pit—whether from a shaft fire or from an outbreak above bank—have only to retreat behind the reserve doors and make the latter air-tight after closing them. Their next task is to warn the miners in the workings of the danger, so that the latter may escape by the upcast air shafts,

which they will have time to do in safety if all the doors have been simultaneously closed on the various levels.

Valuable service may also be rendered by these doors in other pit accidents, such for instance as a fire in a timbered intake cross drivage—or in a stable situated therein—opening into the shaft, and from which smoke fumes might be conveyed with the air current into other parts of the workings. Thus if the miners have fled from such a fire centre to the shaft, the rescue of all in danger may, under certain circumstances, be facilitated by the closing of such reserve doors and stopping the current of air or smoke. Of course care would be necessary to ensure a provision of fresh air from other ventilating currents to the endangered miners.

The greatest degree of danger in pit fires arises when only a single intake air shaft is available, because in such event any injury to the main intake current is fraught with great danger to the whole of the staff in the mine. If it has been possible to close all the doors in the various intake levels the burning shaft will thus be isolated and the endangered men saved. No well-founded objection can be urged against a short stoppage of the intake air current and fan, since the staff will be rescued in a very brief space of time and the extinction of the fire can be afterwards even more quickly accomplished by deluging it with water, whereupon the doors can be immediately reopened and ventilation resumed. It is advisable to make the loading places in the shaft fireproof and to construct the reserve doors of iron.

Where the pit is provided with several intake air shafts, the danger to the underground staff is reduced considerably; since, in case one of the intake currents is affected, the others will serve to preserve safety, in case the prescribed procedure for rescue work proves unsuccessful. Such a contingency will also ensue in pits with only a single ventilating intake, when the doors on only a few of the intake levels can be

closed, because in this case the miners can assemble in those portions where the smoke fumes are shut out, and wait until further steps are taken to get them out in safety.

Should the pit be ventilated by a number of separate air systems from different intakes, it is advisable to keep the separated currents as close together as possible, in order to facilitate the flight of the miners from one system to another in different parts of the pit.

Precautions to be taken in case of failure to isolate a burning shaft.—It has already been stated that a burning shaft will soon begin to act as an upcast ventilator. This, however, will not always happen with sufficient rapidity—especially when the ventilating current is very strong—to enable the total underground staff to be rescued. As under these circumstances a brief interval of time may be of the utmost importance the following arrangement devised for the twelve intake (winding) shafts at the Kaiser-Ferdinands-Nordbahn colliery at Ostrau are of interest. Here the precautions adopted enable the ventilating current to be reversed in the intake shafts immediately the fans have been stopped, so that each shaft can be converted—though with a limited degree of efficiency—into an upcast. To effect this, not only is the shaft closed by flap doors on the curb, and the air diverted through a lateral conduit, so that the ventilation can be maintained after the burning shaft is closed at the top, but this conduit is also connected with the boiler chimney. Ordinarily the conduit is kept shut by means of a sliding damper which is only opened when the ventilation is to be reversed. In most of these shafts a Körting injector exhaust apparatus is fitted up at the mouth of the conduit, and can be started directly the shaft doors are closed and the damper opened.

The general arrangement is shown in the sketch, Plate I., Fig. 6. Here S is the winding and air intake shaft over

which are fitted the iron flaps, G H, mounted on hinges and raised or lowered by winches, M and N. The passage way, F is also fitted with an iron door at the top, and branches off near the mouth into the ventilating or safety conduit, K, which, at its further end (12 to 20 yards, or more, distant) is fitted with a Körting exhaust, E, fed through a steam pipe, D. The form and dimensions of the conduit are set forth in the cross section through, A-B. In the event of a fire in the pithead buildings, the door, T, is opened and the conduit is utilised for admitting air and for rescuing the men underground. If fire breaks out in the shaft, the door, T, is closed and the injector set to work. In either event the flap doors, G and H, must be closed.

During the last few years a greater degree of strictness has been introduced into the Mining Police Regulations in almost all countries with regard to reducing the risk of fire in shafts. For example, the regulations laid down in 1896, for mines within the kingdom of Saxony, prescribe that:

"Provision must be made in every main shaft for quickly shutting same either at the bank or a short distance below in the event of a fire in the pithead buildings. Moreover, in the case of each shaft used as a passage way and constituting the sole means of exit from the pit, a lateral traversable conduit must be provided and arranged so as to debouch outside the pithead buildings; and the shaft must be lined with masonry or iron from its mouth to the floor level of the said conduit."

The closing of the shaft is to prevent any burning fragments falling from the building above, and thus setting the shaft on fire; as well as to keep back any inrush of smoke and fumes. It was owing to similar precautions that on the occasion of a fire in the buildings at No. 1 shaft of the Zwickau-Brückenberg Colliery in March, 1874, the large staff of miners in the workings were enabled, in spite of the

fire raging above them, to escape through the shaft to which they belonged and make their way to and ascend to bank through another shaft by way of a heading about 330 feet below the surface; and it was on the basis of this result that the new regulations were drawn up. Attempts have been made to exempt lignite mines from these restrictions, but in consequence of the recent fires in lignite pits in Bohemia and Niederlausitz these endeavours have proved unsuccessful, and it has been determined that applications for dispensation must be decided on their individual merits as hitherto. Such exceptions may be constituted by shafts provided with iron head gear and buildings.

This conduit is essential for each shaft used as a passage way so far as such shaft forms the sole means of exit from the pit—an exceptional case—whereas the covering is prescribed for main shafts alone. Nevertheless, exception is frequently considered impossible, both in respect of the covering and also of the conduit; and is only granted under special circumstances when the sinking of deeper shafts for coal mines is in question, *i.e.*, in the case foreseen in the following portion of the regulations, the provisions of a special refuge exit is deferred. According to this regulation the presence of a single exit suffices in the case of a new coal pit or lignite mine until such time as the coal is met with in winnable quantity; and the second exit, which must be provided immediately, is connected with the first by a drivage. Furthermore, even when several shafts are present, the provision of a conduit of the kind in question is of great value, in view of the possibility of a fire in the pithead buildings—at least so far as intake shafts are concerned.

3. Precautions to be Adopted in case those under 1 and 2 Fail or Prove Inefficient.

This contingency occurs, for example, in all pits which are unprovided with safety appliances of the above description and happen to be overtaken by such a catastrophe.

In such event the rescue of the endangered staff and the recovery of the mine must be attempted by special means, namely, rescue or respiratory apparatus (see Chaps. IV. and VI.).

PRECAUTIONS AGAINST SPONTANEOUS IGNITION OF COAL.

To afford protection against this spontaneous ignition of coal, the working should be as cleanly as possible and the packing material dry. The latter should not liberate any great amount of heat in decomposing.

In the case of thick seams the practice is gradually being adopted of packing the workings with rock. Thus, in the fiery mines of Southern Hungary, all seams over 10 feet in thickness are now packed with material, at least part of which is brought from above ground.

The following are the chief difficulties of the pillar system, formerly in general use in Upper Silesia, in comparison with goaf packing.

1. The dangers naturally attending the working of a thick seam in a single stage.

2. The increased influx of water in consequence of roof-falls, a circumstance of the greater importance in proportion as the working is carried on under loose water-bearing strata.

3. The occasional impossibility of taking out the full thickness of very thick seams. The insertion of props of a

length required by the thickness of the seam is out of the question, owing to the insignificant dimensions of the shaft and headings; consequently a certain amount of coal must be left either in the roof or sole; the result being that, when the other customary losses are considered, the amount of coal recovered becomes comparatively small.

4. The often considerable slope of the seam tends to favour spontaneous ignition, in consequence of which evil there arise:—

5. Irregularities in work, consisting in a considerable reduction in the output through the damming up of burning winze workings, and the difficulty and inconveniences of transferring the miners to other parts.

Goaf packing has been employed to replace pillars in the Shuckmann seam of the Königin Luise Colliery, the thickness of which seam attains 46 feet.

The area where this experiment was made measures 98 feet in height and about 660 feet in length. The seam dips at an angle of 55 degrees, and measures about 65 feet horizontally from sole to roof. In order that the work of coal-getting should not be interrupted by the work of packing this experimental section, which is in the eastern portion, two superimposed inclines have been provided on the western side of the section, the upper one being used as a haulage way for coal and the other for lowering the packing. The first working heading is driven from the lowest end of the coal haulage way to the boundary of the field, and the coal is taken out towards home in a horizontal direction, in breadths of 16 feet with a height of 13 feet, right up along the face as far as the incline. In proportion as the work of coal-getting proceeds, so the packing is conveyed to the boundary through a haulage-way 6 feet higher than the other. As the space to be packed is 13 feet high, whereas the haulage-way is only 6 feet above the floor, the

lower 6-foot space is filled by tipping the tubs, and the upper portion is filled up by hand. When sufficient has been taken out of the under layer, a second layer is proceeded with; but, in order to keep the coal from this second layer from mixing with the underlying packing, the roof of the under layer is planked over during the whole time the coal is being taken out. The necessary packing material is obtained from the waste in driving new headings, etc. If this is found insufficient later on, the intention is to use the waste stones from the washing plant for the same purpose.

The coal districts of Upper Silesia have very frequently been the scene of pit fires. A detailed description will now be given of the methods employed for combating pit fires in a Silesian colliery, The Fanny-Chassée, near Laurahütte.

This pit was in work about the beginning of the nineteenth century, but at a very early period difficulties arose from the extremely violent outbreaks of fire.

At first the origin of these was somewhat obscure, and it was thought that they spread from above ground, namely, that, owing to the breakage of pillars in the Fanny seam, near its outcrop, glowing masses of slag from the neighbouring zinc smelting furnaces had fallen into the mine, along with other débris, and produced the fire.

At first it was imagined that the extension of the fires could be effectually prevented by isolating the workings with dams of wood and masonry, but it was very soon found that such hopes were illusory. On the one hand, the dams could not withstand the heat and pressure, and, on the other, coal began to crack near the dams, so that the inrush of gas and fire into the workings could not be prevented. Even when the dams were carefully plastered with lime, the fire frequently ate its way through the fissures filled with fine coal dust, the consequence being that the coal in front of the dams often took fire, and the same extended to the timber.

There was then no other course open than to pull down the burning coal by the aid of long hooks and quench the fire with water from hose, a task naturally one of great danger. Not only did the men suffer a great deal from the heat, but it not infrequently happened that the ventilating current suddenly reversed and drove the smoke and fumes in their faces. Under these circumstances it was often a matter of great difficulty for the workers to make their escape by retiring behind a second so-called "rescue dam," which was already prepared and could be quickly closed, the doors being set ready for hanging near by.

Necessity soon arose for abandoning whole portions of the field, but still it was found impossible to entirely exclude the fire from the workings. To attain this object, trials were made with water-tight dams, behind which water was let down from the bank until the fire was properly extinguished. Nevertheless, the dams and coal pillars could not stand the weight of the accumulated water, and the latter broke through into the low-lying workings. The water itself, when it traversed the seat of the fire, was naturally rendered acid by the combustion products of sulphur, and began to corrode the pumps. In consequence of the defective results attending this attempt, and the heavy expenses, this method of combating the fire was finally abandoned, and recourse was had to a means from which success was confidently anticipated.

On the basis of the aforesaid hypothesis that the fire was communicated from the above ground to the old workings it was still thought justifiable to conclude that, if the fire could be completely dammed up, its extinction would follow. Consequently in the three seams[1] the 10-foot thick pillar of coal

[1] The Fanny seam (the upper seam), 26 inches thick.
Glück's seam, 6½ inches thick.
Caroline seam (lower seam), 19 inches to 23 inches thick.
The rock between the two upper seams consists of bituminous shale

was left standing all round the seat of the fire, and masonry dams of sufficient strength were very carefully built in all the headings traversing this pillar. It was thought that this measure had proved effective, because a few of the sections near the pillar were successfully worked out; but suddenly the fire broke out anew in the Fanny seam, in newly-cleared workings entirely distinct from the seat of the old fire.

As the cause of this could not be attributed to negligence or malicious action, and further as it was impossible the fire could have been communicated from above ground, the opinion was finally arrived at that the coal had a tendency to spontaneous ignition.

In order to confirm this view large masses of coal were thrown up in heaps above ground. Nevertheless, contrary to expectation, no ignition occurred. Simultaneously, however, it was noticed that the fire invariably occurred in the two upper seams but never in the Caroline seam. Attention was therefore directed to the nature of the rock accompanying those two seams, and it was found that this contained layers of bituminous shale plentifully interspersed with pyrites. Experiments immediately confirmed the decomposition of this pyrites as the cause of the pit fires, 100 tubs of this rock recovered from the goaf and tipped in a heap above ground taking fire in a very short time.

Although this proved that the cause of the pit fires must be ascribed to the spontaneous ignition of this fiery shale in the goaf, nevertheless the fact remained that the fire would continually follow the further working of the pit. Consequently the task arose of arranging the ventilation methods of working, etc., in such a manner as, on the one hand, to

thickly interspersed with pyrites, and measures about 10 inches thick; that between the two lower seams consists of shale and cloddy sandstone, and measures over 80 inches thick. All three seams contain very pure coal, and are full of fissures with fine coal dust.

restrain outbreaks of fire as long as possible, and on the other hand to keep within narrow limits any fire that should arise.

The consideration that a certain amount of time is necessary to the decomposition of the fiery shale naturally led to attempts to utilise the interval, between the commencement of working and the outbreak of fire in any given section, for clearing the seam of coal. As, however, the pillars could be worked quicker in proportion to the number of points of attack, it was decided to work the sections from both boundaries at once. Furthermore, the length of the individual sections was made smaller than formerly, and in fact limited to 330 feet. As, however, this reduction in length enables a larger number of winzes to be worked simultaneously, it was considered that in case the necessity should arise for isolating individual sections there would still be a sufficient number of working points available. In order to enable the section to be shut off at any time without delay, the heading driven from the draining level to the first working face, and also the incline, were provided with masonry dams 40 inches thick, deeply sunk into the walls, roof and sole. Openings were provided in the dams of the inclines and both haulage ways. for the purpose of haulage and ventilation, sufficient bricks and mortar being kept near by to rapidly close these openings in case of need.

The coal in all three seams being very much fissured, the headings were plastered over with mortar on roof, walls, and sole, for some distance, to prevent, on the one hand, the access of fresh air to any fire that might break out, and, on the other, to keep back the smoke fumes from penetrating the other workings in the pit.

The method of ventilation formerly employed was that in general use in Upper Silesia, *i.e.*, the air current was directed along the lower heading into the different sections and allowed to stream along the working face, escaping

thence through an air way on the upper boundary of the workings to the upcast.

This system, however, did not answer at the Fanny-Chassée pit, the fumes from the seat of the fire rendering the air way impassable and preventing the execution of repairs to the timbering. Consequently the air way was frequently obstructed by falls, and the fumes thus prevented from escaping were driven back into the working sections farther in the rear, so that it became necessary to provide special and separate ventilation for each section. This, however, could only be done by appointing a separate way for the waste air from each, which was effected by sinking separate boreholes to serve as upcasts near the upper limit of the workings in each section. As in many cases the draught was insufficient to ensure proper ventilation, chimney shafts about 30 feet high were built over the mouths of the boreholes, or else Körting injectors were provided to increase the draught. By this means the air current can be kept under control, a circumstance of great importance in case of fire.

When the preparatory work of fitting out the section has been completed, and the masonry dams put up, the coal is got in the usual manner. In order, however, to enable as many stalls as possible to be worked before the dreaded outbreak has time to develop, the working places are strongly manned and coal-getting proceeded with at a very rapid rate. Wooden doors are erected in the heading immediately in front of the stalls in work, in order to entirely cut off the supply of fresh air when the work is suspended.

When a fire occurs, the particular section attacked is abandoned and the masonry dams are made air-tight, so as to cut off the access of air to the fire. In order, however, to afford a means of examining the progress or extinction of the fire, the main dam in the lower heading is provided with

a circular peep hole, closed by a wooden plug. A thermometer is also hung against the dam to indicate the rise or fall of the temperature behind the latter. Should a *persistent* diminution be observed, and no outrush of smoke and hot air can be detected on opening the peep hole, then work may be resumed after a copious supply of air has been passed through the isolated section for a considerable time, in order to drive away the accumulated choke-damp. After inspection with a safety lamp, the necessary recovery work is then undertaken as quickly as possible, and work is resumed until another outbreak of fire necessitates its cessation once more and the repetition of the precautions described above.

It having been discovered that the fires are fed with air penetrating into the goaf through surface fissures, all cracks that can be detected are carefully filled up and rammed tight.

Since the introduction of all those precautions the proportion of waste in working has been considerably reduced, and the work can now be carried on with regularity and greater safety to the miners engaged.

Goaf packing is becoming more and more appreciated in the Zwickau Colliery (Saxony). Where there are two seams separated by only a short interval and fire breaks out, or is feared, after the upper one has been worked, the underlying seam is taken out, packing being resorted to, because, in robbing, the roof would fall and admit fumes from the upper seam. In re-opening a section closed on account of fire, the whole workings are packed in many of the pits. At several collieries, packing is used in the slow task of taking out thick seams having a tendency to ignition, because this procedure obviates the removal of props and the breaking down of the coal-bearing strata of the roof, even the expense of raising the packing by means of air winches being often willingly incurred. In the soft coal seams in the north-west field of the Wilhelm, No. 1, shaft of the Zwickau-Oberhohndorf Colliery

Company the method pursued for many years of taking out the under six-foot seam first, packing the goaf, and then working the upper eight-foot seam, has proved satisfactory, enabling the coal to be taken out clean, preventing fires, increasing the safety of the men and giving a larger yield of lump coal. The system of goaf packing has also proved the best method for enabling the coal to be taken out clean and preventing roof falls and pit fires, in several other collieries in the same district.

Again, at the Kaiser pit, Gersdorf, the main seam is taken out first and tightly packed, in order to obviate the constant danger of fire breaking out in the sections where the intermediate strata between the main seam and the overlying Vertrauen seam was only 40 inches thick, the latter seam being taken out later. Up to now this precaution has been successful, and it offers the additional advantage that the timbers, employed in working the first seam, can be used over again. The main seam, in the southern portion of the field, where it attains a thickness of over 10 feet, is also taken out clean and packed. The repeated attempts made by the author, in the Kladno coal basin of Bohemia, to take out a 20-foot seam in two separate portions, were frustrated on account of the expense.[1]

In every coal district the risk of fire entails special modifications in the preparatory work and method of coal getting, commensurate with the prevailing local conditions. Since, however, even a superficial description of all these points would far exceed the limits of the present work, nothing more can be given than a general *resumé* of the precautions

[1] As far back as 1868 Dworak characterised the method employed at Kladno—undercutting and fall—as wasteful, dangerous to life, and leaving unwon an incalculably large proportion of the coal, whereby an inducement to spontaneous ignition was afforded. Nevertheless, on account of the prevailing conditions of competition, it has been impossible up to the present time to substitute a method in which packing is employed.

adopted against the spontaneous ignition of coal, and naturally these will not meet the requirements of every case. They are as follows :—

(*a*) Getting out the coal as clean as possible.

(*b*) Efficient goaf packing (a very efficacious but costly preventive).

(*c*) Isolation of abandoned sections by means of substantial dams, after clearing out the pillars of the bord and pillar system.

(*d*) Avoiding the practice of opening too large a working section by means of headings and pillars at any one time, and making it a rule to finish up a section as quickly as possible after it has been commenced.

(*e*) The entire removal of all small coal from the workings.

(*f*) Ventilating the heaps of smalls by means of bricked air conduits or large faggots, or totally immersing them in water.

(*g*) Carefully removing all water from the workings.

(*h*) Providing a brisk ventilating current wherever the coal is of a readily inflammable nature.

(*i*) Stopping up air-tight all cracks and fissures in the coal.

Successful use in combating pit fires can be made of the supply of water under pressure provided in many pits for removing coal dust, and for special ventilation purposes.

The complete isolation of the goaf is never attained by means of dams, and the slight draught consequently traversing the goaf has always the advantage of preventing accumulations of fire-damp in the old workings, although it greatly facilitates the spontaneous ignition of any residual coal and timber therein. In addition to this, any total exclusion of air would probably cause a rise in the goaf temperature.

With regard to the necessity for partly isolating fiery sections of the workings by means of dams, before any actual

outbreak, this question has previously been treated by the author in a pamphlet on an explosion of coal dust at Anina, the explosion itself as well as the succeeding pit fire, and the recovery work consequent thereupon, being dealt with in the following terms:—

"On consideration of the numerous dangers attending the isolation of the seat of a pit fire by dams, after an explosion or an outbreak of fire, and how frequently it must happen that such dams can then be put up only in a very hasty fashion, thereby forming a centre for fresh catastrophes; furthermore, how often the dams so erected prove worthless owing to the lack of time necessary to the selection of the most suitable position for same; it would seem advisable to provide the ways, leading to particularly dangerous parts of the workings, with doorways of masonry before an outbreak of fire or an explosion. In several of the Kladno collieries (Bohemia), even where no fire-damp has to be combated, doors of this kind are built in before the commencement of coal getting, so that any fire occurring in the working section can be immediately isolated by dams. Strong log doors accurately fitting these doorways are placed ready near by, and can be put in position on the occurrence of an outbreak, the remainder of the aperture being then bricked up immediately."

In one instance, at the Bresson shaft (Kladno) the author succeeded in thoroughly isolating an extensive fire centre perfectly air-tight by this means within the term of an eight-hour shift. These brickwork or cement doorways would be valuable both in case of a true pit fire and of a fire caused by one or more explosions.

In each level at the Ferdinand Colliery[1] (Myslowitz-Kattowitz district), brick dams are provided in the vicinity

[1] *Zeitschrift für Berg-Hütten- und Salinen-Wesen*, 1898, vol. 46, p. 129.

of each shaft, and enable the various shafts to be completely isolated from one another and from the workings. A diagram, showing the relative position of the dams, galleries, and shafts at the various levels, is hung up in the office of the responsible manager, and each official on the works is provided with several copies, in order that any strange officials, offering their assistance in an emergency, may be able to find their way about in the mine without delay. Their difficulties are lightened by the fact that the dams are legibly marked with numbers, both in the drawings and in the pit. A similar arrangement is being carried out in other large collieries in this district.

The method of working by means of sloping ways driven round the field, such as is practised in Anina, in the drainage galleries, in the unworkable under seam, 33 feet from the main seam, cannot be regarded as a preventive against pit fires, though the presence of such ways greatly facilitates their extinction. In one case, owing to the absence of such a way, the pit had to be abandoned, and in another the provision of a heading enabled an extremely dangerous outbreak of fire to be localised. Furthermore, the ventilation of and haulage in other parts of the workings can be effected through these headings whilst a fire is in progress, so that their construction, in the course of driving through unworkable seams or mild rock, may be warmly recommended when local geognostic conditions permit. The apparently high cost is often counter-balanced by the fact that such a heading will form a second haulage way, and that, where the seams are exposed to heavy pressure, the lower gallery can be quickly abandoned and the whole of the ventilation, drainage and haulage carried on in the more permanent heading. In this event the goaf above the drainage gallery can be shut off quite air-tight by dams in the connecting cross-drivages.

The great importance of having a powerful current of

fresh air always available when a fire has to be extinguished, has been shown in the case of numerous fires in the coal pits of Southern Hungary. Again in the Maria Colliery (Aachen) the fire in one section of the 1,837 foot level was extinguished by passing the whole of the ventilating current—about 21,200 cubic feet per minute—directly through the wing leading to the seat of the outbreak, this being done in order to enable the necessary measures to be adopted for putting out the fire. The highly risky experiment succeeded, the immense volume of fresh air cooling down the headings to such an extent that the men were able to work right underneath the flames and to continually reduce the burning area by erecting dams of clay and turf, total extinction being accomplished after fifty-three hours' strenuous labour.

In many pits the artificial admission of water is successfully employed for keeping down the temperature of the coal pillars. At the Bach lignite mine, near Ziebingen, the coal, in one of the seams worked, is liable to crack on drying, and to grow hot in consequence of the ensuing absorption of air. If, however, a copious supply of water is provided to keep the cracks closed, this heating is prevented. The amount of water daily required is sometimes as much as 10 litres (22 gallons) per cubic metre (35·3 cubic feet); the pit water raised by the pumps being collected in tanks and utilised for this purpose. It is conveyed down to the air-way, through branch tubes of $\frac{4}{5}$-inch gaspipe and hempen hose piping attached to the ends of same, and allowed to run over the floor in suitable places so as to trickle down through the cracks in the coal and drain into the working sole twenty feet deeper, where it is run off to the pumps along with the rest of the pit water. Its temperature rises to a not inconsiderable extent in passing through the coal. By this means the readily inflammable coal is prevented from taking fire, the air is kept cool and fresh, and the working capacity

of the miners is therefore increased. Moreover, it affords the advantage, by no means small, of leaving the pillars perfectly intact, so that they can be taken out quite clean. Water being plentiful, the seam pillars can be sprinkled uninterruptedly; and, in the event of fire, rose jets can be screwed on to the pipes and employed for extinguishing the outbreak.

PRECAUTIONS FOR PREVENTING EXPLOSIONS OF FIRE-DAMP AND COAL DUST.

So comprehensive are the precautionary regulations for preventing explosions of fire-damp and coal dust—the latter being in turn a cause of pit fires—that their reproduction, if only in brief, would fill an entire book. They extend not only to the operation of blasting and the use of safety lamps, which play an important part in the majority of explosions, but also to the arrangement of the whole system of ventilation. Special reference may be made to the regulations issued in this connection for the Mährisch-Ostrau mining district, under date 27th October, 1895, which in the main adhere to the Dortmund Mining Police Ordinance of 1887, but in several respects have been amplified.

The *safety lamp* plays one of the weightiest parts in the technology of fire-damp, its property of affording the most suitable means available for the detection of inflammable gases, having been the cause of the attainment of the high degree of safety now usual in coal mining. Besides rendering human life secure, the safety lamp also preserves the workings, and the high value in which it must therefore be held is indisputably confirmed by the statistics relating to mining accidents.

Out of the hundreds of different lamps based on the principle of the Davy lamp, not more than half a dozen kinds have made their way into use for fiery pits. The

reason for this is that, in addition to the maker's principal object, namely, to prevent the flame from flaring through the gauze the safety lamp has to fulfil a number of requirements, such as power of resisting injury, delicacy of indication, cheapness of maintenance, etc.

Among this restricted number of types the most perfect at the present time is the Wolf benzine lamp, which is very largely used in Germany and Austria, and is already beginning to displace other kinds in the remaining mining districts of the Continent and America. Under the influence of the high-speed ventilating currents now essential in large, deep mines, in order to properly ventilate the numerous working places where fire-damp is liberated, the other types of safety lamp no longer afford sufficient security. As the excellent points of the Wolf lamp, fed with benzine, fitted with ribbed protective mantle, friction ignitor, magnet locking device, and container of tempered metal, cover the requirements exacted of a modern safety lamp, its principal advantages, in the greatly improved form developed since 1883, are briefly subjoined:—

1. The illuminating power is constant, at $1\text{-}1\frac{3}{10}$ normal candle power, throughout a whole shift, whereas that of the best rape oil lamps averages only $\frac{5}{10}$ - $\frac{6}{10}$ of 1 normal candle power. The bright, uniform light, and the ease of ignition greatly increase the working capacity of the miner, and, unlike the old oil lamp, there is no need to prick at the wick. The cost of the benzine consumed is only $\frac{1}{3}$ that of rape oil, and another saving ensues from the longer life of the wicks.

2. The benzine lamp is a very sensitive indicator of fire-damp, $\frac{3}{4}$ per cent. of inflammable gas being detectable with a little practice.

3. It possesses a reliable locking device.

4. The closed lamp can be lighted without danger; hence, after an explosion—whereby it often happens that the whole

of the lights in the pit are extinguished—the miner is able to relight his lamp without danger, and save not himself alone but also his probably insensible comrades.

Notwithstanding the frequent endeavours for many years past—in fact since 1846—both in mining circles and the legislature, to have all lamps of the Davy type superseded by the electric light, the latter is still not very widely used in mines, although highly serviceable for certain purposes, especially in recovery work after a fire, the lighting of loading places, etc. The miner's electric lamp lacks the special property of the safety lamp, *viz.*, of indicating the presence of fire-damp by the altered appearance of the flame. Moreover, even the electric lamp may occasionally give rise to explosions; as was the case for example during the recovery work after the Karwin fire in 1895, where a fire-damp explosion was produced through the striking of an electric lamp against the tools carried by one of the workmen. Numerous experiments in Ostrau, and those performed at an earlier date (1890), by Mallard, Le Chatelier and Chesneau, have shown that the incandescent carbon filament of the electric lamp, when white hot, is capable of igniting fire-damp; and though when merely red hot the filament does not produce ignition, neither has it any illuminating power whilst in that condition. The experiments of the Ostrau Fire-damp Committee showed that the breakage of an incandescent lamp (5-6 volt and 0·5 ampère current) in an atmosphere of fire-damp seldom produced ignition, the carbon filament being usually ruptured by the shock of breakage. On a small hole being made in the glass bulb ignition seldom occurred, even if the filament remained intact; though, on the other hand, an explosion invariably ensued in the testing apparatus, on a large aperture being made in the lamp and the filament raised to white heat by the passage of current. Nevertheless, electric lamps are

the most suitable of all for use in a fiery pit atmosphere. The small electric glow lamps of the original Bristol type, such as are used at Karwin, are hemispherical, measuring 1¾ inches across, the glass (¼-inch thick) being protected by a strong brass cross. Of course these lamps are not *absolutely* safe, since all manner of accidents or damage may arise through carelessness.

With regard to the influence of *blasting* as a cause of fire-damp explosions, the following table, drawn up by Winkhaus, gives the minimum quantity of various explosives capable of producing ignition :—

Explosive.	Charge in grams.	CH_4 per cent.	Charge in grams.	Per centage of gas free from coal dust.	Charge in grams.	Percentage of gas in presence of coal dust.
Gelatine dynamite . .	75	2·25	50	6·2	45	6·5
Guhr dynamite . . .	75	,,	58	6·5	30	6·8
Rock karbonite . . .	111	,,	81	7·0	—	—
Sekurite	50	,,	150	6·4	—	—
Roburite	152	,,	154	6·1	130	5·8
Wetterdynamit	200	,,	68	6·3	51	6·6
Westfalite	300	,,	251	7·0	250	6·3
Dahmenite	500	,,	251	7·1	250	6·3
Progressite	—	,,	550	6·75	560	7·25

According to A. Siersch's instantaneous photographs of the flame produced by 100-gram cartridges exploded in a state of free suspension, blasting explosives may be divided into two groups :—

I. Flaming (dangerous) explosives: ordinary black powder, gelatine dynamite, and kieselguhr dynamite.

II. Safety explosives: coal karbonite, roburite 1, new Westfalite and Dahmenite A.

According to the dimensions of the flame, black powder is the most dangerous of Group I., whilst Dahmenite A is the safest member of Group II.

From determinations made in respect of the *effective power* of different explosives by noting the amount of distention produced by exploding 20-gram charges in leaden cylinders, their relative strength increases in the following order: Dahmenite A, new Westfalite, roburite 1, coal karbonite, gelatine dynamite 1.

Official reports[1] on the blasting experiments conducted with safety explosives in fiscal and private collieries in Saxony "black powder is not extensively used anywhere but in the Hänich pits, the reason given for its employment there being the larger proportion of lump coal it brings down and its relatively lower cost (¼-½) than safety explosives. Of the latter class, coal karbonite and roburite 1 are most largely used. With regard to the proportion of lump coal brought down, and the force and composition of the gaseous products of explosion, Westfalite is on a par with roburite; but preference is accorded to the latter because it enables weaker cartridges and detonators to be used without inconvenience. At the Von Burgker collieries the proportion of lump coal obtained by using roburite or Westfalite was about 3 per cent. higher than in the case of karbonite; the latter, on the other hand, proving suitable in compressed pillars with fiery coal. At present the relative proportion of explosives consumed in these collieries is about 70 per. cent. of roburite and 30 per cent. of karbonite."

EMPLOYMENT OF ELECTRICITY IN MINING, PARTICULARLY IN FIERY PITS.

In comparison with the position it has attained in other industries, electricity may be considered as but little employed in mining, although here the conditions are exactly those under which this force should prove extremely useful, namely the transmission of power for considerable distances from the

[1] *Freiberger Jahrbuch*, 1897.

generating station. Probably the chief cause retarding the application of electricity as a motive power for underground machinery is the dangerous nature of high-tension currents. As a matter of fact, currents of such high tension as is requisite for mining work must necessarily be very carefully dealt with, as many accidents have already demonstrated in a very serious manner.

Chiefly to be borne in mind are the accidents, often attended with fatal consequences, resulting from contact with live wires, whether through carelessness, misadventure, or by a current being sent in error through a conductor whilst the latter is in the hands of the workmen. In mines, the chief danger to be considered is that of fire, and, in coal pits especially, the risk of fire-damp explosions caused by the electric current. Nevertheless the resources of electric technology are sufficient to obviate all these risks, and consequently, official mining regulations have already been issued, based upon the provision of suitable insulation of all live wires, the reduction to a minimum of the risk of sparking at any part of the conductors or moving parts of the machinery, and the provision of air tight metal cases for all parts where sparking cannot be altogether prevented.

Preference should be accorded to the rotary current system, *i.e.*, rotary-current motors, owing to the absence therein of the sparking produced at the commutator of continuous current motors. They also afford the inestimable advantage of dispensing with the troublesome task of cleaning the commutators. Nevertheless the rotary-current motor is not entirely free from defects, at least under certain circumstances, which will now be investigated.

In order to comply with the official regulations enjoining the employment of motors with the lowest tendency to produce sparking, those fitted with collecting rings must be avoided, and only those of the short circuit type used.

When the current is passed through the fixed part of a rotary-current motor, the onward movement of the poles in the field of rotation induces currents in the windings of the movable armature. Consequently, the rotating poles exert a certain pull on the current-bearing coils, and the whole armature takes part in the rotary movement. The more rapid the rotation of the armature, the weaker are the currents in the short-circuit coils, and the lower the tension exerted on the armature, so that finally, when the armatures and poles are moving at equal velocity, the coils are free from current and the tension is reduced to *nil*.

In this event the armature moves in synchronism and cannot attain a higher speed, by reason of the braking action that would ensue from the currents thereby generated.

Moreover, even when the motor is working under load, the speed of the armature varies but slightly, the number of revolutions decreasing by only a small percentage; and it is this property of the rotary-current motor that constitutes both its great advantages and inconveniences for driving machinery in mines. For example, the aforesaid property is extremely favourable so far as pumping is concerned. Mining pumps, being mainly required to work regularly without supervision, have to be run at a uniform rate of speed, which should not greatly deviate from the normal, in case the load is suddenly removed, *e.g.*, when the pumps no longer lift. In such event, pumps driven by steam or compressed air would infallibly run away, and might be totally ruined by the excessive speed. On the other hand, such a contingency has no further effect on the rotary motor than to reduce the amount of current consumed to the quantity required to drive the empty pumps.

The ordinary rotary motor is also the only correct form for driving ventilating fans and, under certain circumstances,

for rope haulage. It invariably acts in a perfectly satisfactory manner.

Nevertheless, difficulties arise when it is a question of driving machinery liable to carry overloads for prolonged periods. In this respect winches are the worst. The credit of having solved the problem of ensuring perfect reliability in rotary-current winch motors, both as regards the regulating of driving and in respect of the electrical ignition of fire-damp, so that no attendance is required, is due to Siemens and Halske of Charlottenburg. To go, however, into this matter would extend beyond the scope of this work, and the reader is therefore referred to R. Friedemann's admirable treatise on the employment of electricity in mining, the most important parts of which are now reproduced.

Special attention must also be bestowed on the security of the means for distributing the current. In erecting the underground motors at the Kaiserin Augusta Shaft at Oelsnitz (Saxony), Friedemann adopted as a fundamental rule that not only should naked contacts be entirely excluded, but also that it is indispensably necessary to entirely prevent the sending of current, whether by accident or ignorance, through any part of the line where those engaged in any work on the line are liable to come in contact therewith.

The conductors consist exclusively of cables protected from external injury by a strong covering of wire; and where this covering is impossible, *e.g.*, at the lamp terminals in loading places, or in the line terminals on the motors, the conductor must be enclosed in strong wooden casing. This precaution must on no account be disregarded, because, when the conducting wire is left unprotected, it may easily happen that, as a result of carelessness on the part of the men—who are usually insufficiently acquainted with electrical matters—the wire is pulled out of the clamps, or, if the latter holds tight, may become broken. Again, in laying cable in the

shaft, regard must be had to the circumstance that the wood used for carrying the cable is liable to rot and shrink, and, therefore, subject to movement, especially in the places where there is heavy pressure. It is advisable, in the case of wooden shafts, to hang the cable between iron bars entirely independent of the shaft timbering and set in the rock, as far as possible from the winding gear, as shown in Plate V., Figure 19, in which *a b* are the iron bars, K the cable, and s_1 s_2 the connecting screws joining a pair of oak cheeks.

When the conduction of a continuous current is in question, which, under the influence of the acid pit water, may exert a chemical or destructive action and also readily injure the lead casing of the cable in uninsulated places, the wooden clamps must be placed on porcelain insulators.

The distance between the supports for the shaft cable depends chiefly on the thickness and weight of the latter. In any case great care is necessary to see that the wooden clamps are not too tightly pressed together; otherwise the sectional shape of the cable may be altered and short circuiting be readily caused by the resulting approximation of the conducting wires. Provided, however, that some soft material, like tow or pieces of old driving belts, is inserted, the distance between the supports of a freely suspended cable 2¼ to 2½ inches thick can be as great as 16 yards without any objection.

In the case of a heavy cable, the suspension in the shaft is attended with some difficulty, since it must not be exposed to considerable pressure, and, therefore, the radius of curvature must not fall below a given dimension. The minimum is fifteen times the diameter of the cable. The safest way to hang the cable is to attach the same to the winding rope, at intervals of about 3 to 6 feet, by inserting between the cable and the rope pieces of wood hollowed out on either side, the whole being bound together by means of soft $\frac{1}{12}$-inch

binding wire, each binding being about 2 to 3 inches in length.

EXPERIMENTS ON THE IGNITION OF FIRE-DAMP MIXTURES AND CLOUDS OF COAL DUST BY ELECTRICITY.

Experiments with regard to the ignition of fire-damp mixtures and clouds of coal dust by electricity [1] were carried out in the experimental gallery of the Westphalia Berggewerkschaftskasse at the Consolidation Pit, III. and IV., the results of which are summarised below. Although these experiments are not decisive with regard to the suitability of electricity for fiery mines, they nevertheless constitute a foundation for further measures. On the one hand, electrical manufacturers have to utilise the experience gained, and bring upon the market an apparatus of greater safety in fire-damp atmospheres; and on the other, the experiments on the safety of new types will have to be carried out. Speaking generally it may be stated that the amount of electrical energy capable, under certain circumstances, of igniting fire-damp is extremely small. A closer examination of this amount is impossible, because, in addition to the amount of energy, the manner of its disengagement (whether by sparking, arc lights, or glowing carbon filaments and wires) and subsidiary circumstances, come in question. It is only in the case of a circuit, the conditions of which are accurately known, that actual reports can be made on the limits of safety in different methods for the conversion of energy. In any case, all visible sparks are *primâ facie* to be dreaded, but experiment alone can decide as to the harmlessness of some kinds of sparks.

Independent explosions of coal dust are, unless in very exceptional cases, apparently impossible to produce by the action of electricity alone. With regard to individual points

[1] *Glückauf*, 1898, 1, 2, 3.

the following additional conclusions may be drawn : Portable glow lamps (accumulator lamps) must be carefully handled to prevent breakage of the glass bulbs. Appliances to cut off the current in case of pressure or shock on the bulb are useful and desirable. The sparks occurring when the lamps are disconnected are harmless. For lighting loading places in the shaft, or headings, cross-drivages, and during shaft sinking, with fixed lights, high volt glow lamps of not more than 0·5 to 0·6 ampère current are advisable. In these lamps care should be taken that the metal conducting wires carrying the carbon filaments project as little as possible beyond the filling of the base, so that, in case of breakage of the bulb, the wires could not come in contact with each other and produce short circuiting.

It is inadvisable to have two carbon filaments, one behind the other, in a glow lamp, because this increases the danger of short circuiting. For the same reason a higher tension than 150 volts appears at present unsuitable. Each lamp should be provided with a protecting bell of thick glass, in order that the carbon filaments could not possibly survive the breakage of the two glasses by the application of external force. The spark formed on disconnecting a single lamp of not more than 0·5 to 0·6 ampère in a lighting circuit is harmless, unless extraordinary self induction follows.

If these precautions are observed, a well-arranged method of illumination by fixed, high volt glow lamps ought to be safer than any other method in fiery situations. Perhaps in the future, when pits are lighted throughout by electricity, special or very dangerous parts of the workings (*e.g.*, hewing places) will be lighted in this manner. Arc lamps cannot be used in fiery pits. All switches, except those specially named in the treatise, and all fastenings, must be enclosed in an air-tight manner.

Such parts of the starting resistance as are liable to give

off visible sparks must be rendered fire-damp proof. The heating, and occasional glowing, of the wire spirals is not dangerous; nevertheless, care must be taken that the wires inside the resistance are not insulated with combustible materials.

Small, continuous current motors may easily cause ignition, on account of sparking at the collectors. Larger motors of this type are harmless if kept in perfect condition, carefully attended, and in normal work, even though sparks cannot be entirely avoided. These conditions, however, are seldom met with in mining work, and it is therefore advisable to completely enclose continuous current motors placed in fiery situations, or else to enclose only the sparking portions in a fire-damp proof manner.

Rotary current motors with short circuit armature winding, or with collecting rings containing two brushes or fitted with air-tight centrifugal connections in opposition, are sparkless and harmless in ordinary work, but such as are provided with hand connections in opposition, are objectionable on account of the unavoidable sparking, although up to the present no ignition has resulted from the use of such motors in the experiments made. The only instance when danger is likely to arise from the electrical sparks in blasting is when the conductors have been carelessly laid. Incandescent ignitors and split incandescent ignitors are almost harmless and, under certain circumstances detailed in the aforesaid treatise, are completely so.

III. INDICATIONS OF AN EXISTING OR INCIPIENT FIRE.

Sweating of the shale and coal, the disengagement of heat, oppressive warmth, the appearance of foul air, foul smell, difficult breathing, lamps badly burning, all indicate an existing or incipient fire. Smouldering fires generally reveal their presence by a characteristic smell which, *e.g.* in the Kladno pits, is often manifested several days before the fire actually breaks out. In several Hungarian collieries attention is generally directed to a fire, not by symptoms of combustion, but by indications of fire already started, *e.g.*, an unusual degree of heat rapidly attaining as much as 125° F., and finally by a tarry smell and smoke rising from the workings.

In several pits in the lignite district of North-West Bohemia the ready spontaneous ignition of the coal, which is due to its columnar structure and to the circumstance that the fissures are filled with fine dust, constitutes the imminent danger of fire-damp explosions.

Frequently, the time occupied from the commencement of smouldering to the complete outbreak of a bright fire is not over an hour, without any evolution of heat or smoke having been noticed. The occurrence of fissures filled with fine dust increases this danger to a considerable extent.

Fire hose and water pumps are always kept ready. On the occurrence of fire the walls of coal are drenched with

water, and immediate measures are taken to get out the glowing coal. The precautions necessary to prevent the possibility of spontaneous ignition will be evident from the circumstance that, at the Pluto shaft near Weisa, seventeen men are employed on the average in each shaft for clearing away coal dust.

Good service in the timely detection of a threatening outbreak of fire will generally be afforded by taking careful observations of temperature, especially in the upcast airways.

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IV. APPLIANCES FOR WORKING IN IRRESPIRABLE GASES.

Pit fires or explosions of fire-damp and coal dust fill the workings, either partly or entirely, with poisonous, stupefying, or suffocating mixtures of gases, and make the necessary rescue work difficult, dangerous and even impossible. In the case of explosions of magnitude the after-damp almost invariably prevents the rescue of the miners cut off in the pit, and, in the case of pit fires, the suffocating gas causes great inconvenience to the men engaged in localising and extinguishing the fire.

It is still the opinion that a great majority of fatalities in explosions of fire-damp and coal dust are due, not to the destructive effect of shock or force of the explosion, but to the poisonous effect of the after-damp, which, for the most part, consists of carbon dioxide and carbon monoxide. In the case of the fire-damp explosions at the Dreifaltigkeits shaft in Polnisch-Ostrau in 1891, the entire staff of one section of the pit, *i.e.*, about 50 per cent. of the total victims of the catastrophe, could have been rescued had suitable appliances been available. Dr. Haldane,[1] in his work on the causes of death in colliery explosions, states that in three large explosions in the English collieries of Tylorstown, Micklefield and Brancepeth, an average of 77 per cent. of

[1] "The Causes of Death in Colliery Explosions." *Transactions of the Federated Institution of Mining Engineers*, vol. xi., part iii., p. 502.

the total injured fell victims to after-damp, and that the principal part in after-damp is played by carbon monoxide. According to this authority the first decided symptoms of poison by carbon monoxide make their appearance when the blood is saturated with about 30 per cent. of the gas. At about 50 per cent. the power of movement ceases, and death occurs when the saturation attains about 80 per cent. When the amount of carbon monoxide in the air attains 0·06 per cent., human blood will take up 30 per cent in an hour to an hour and a half, so that symptoms of poisoning are exhibited in a worker as soon as he begins to exercise his strength; 0·10 per cent. will produce helplessness at the end of an hour; with more than 0·20 per cent. life is endangered; and, when there is over 2 per cent. of carbon monoxide in the air, death occurs before the blood has had time to attain the maximum degree of saturation (80 per cent.) that the human body can bear and live.

As the majority of miners are not overtaken by after-damp until one or two hours after the explosion, a relatively considerable time is available for attempts at rescue to be made.

Furthermore, the catastrophes in the Ostrau-Karwin district during recent years—and particularly the fire in the Herminegild pumping shaft at Polnisch-Ostrau in 1896—have conclusively demonstrated the necessity for the provision of suitable rescue appliances, kept always ready for use. The number of victims of mining conflagrations and explosions can be greatly reduced when the miners, stupefied by smoke and suffocating gases in the one case and by after-damp in the other, can be quickly rescued; and also when it is possible, by means of suitable respiratory apparatus and rescue appliances, to rapidly repair the damage done to the air-tubing, etc., by the shock of an explosion. These appliances also afford valuable aid in the recovery of a colliery after a fire, since they often enable the area of the fire to be circumscribed

by the rapid erection of dams. It frequently happens that the sole reason for damming-up or flooding an entire pit is that the erection of a simple dam, which would suffice to effect the purpose in view if it could be built in the upcast ventilating gallery, is rendered impossible by reason of the fumes from the fire. At the Herminegild shaft, for example, the accident could have been prevented had it been possible to get at, and close in good time, an open air-door, inaccessible on account of the suffocating atmosphere of the heading.

According to the circumstances under which they are employed, the different kinds of respiratory appliances,[1] such as respirators, smoke masks, rescue appliances, diving gear, etc., may be divided into two classes, namely, gas appliances and water appliances, *i.e.*, appliances for use in these media. The former are more frequently required in mining work than the latter. Mining Councillor Mayer divides all the respiratory and rescue appliances used in mines into two main groups, according to their method of employment.[2]

I. Appliances designed for prolonged use in working in irrespirable gases, such tasks not being limited to any definite time, and for which special preparation can be made. These appliances may be designated "respiratory apparatus," to distinguish them from the second group.

II. Appliances principally used for rescue work, and needing to be kept ready at hand in case of a calamity. They must be portable, and be easily and quickly adjusted and set in order for working. To this class the name "rescue appliances" is given.

Some forms of apparatus are suitable for use under either conditions, though not with equal success in both. Never-

[1] Prof. Kreischer, *Jahrbuch für das Berg- und Hütten-Wesen im Königreiche Sachsen*, 1886, p. 147.

[2] Dr. Fillunger, *Oesterreichische Zeitschrift für Berg- und Hütten-Wesen*, 1896, p. 581.

theless, in practice, the methods of use will always have to be borne in mind, as influencing the successful application and therefore the construction of the apparatus employed.

There are several different types of respiratory appliances, such as respirators, appliances fitted with air-supply pipes, reservoir apparatus and regenerative apparatus. Fillunger, however, divides them into only two classes:—

1. Appliances that can be used for an unlimited time, though at only a limited distance from the source of the air supply.

2. Appliances allowing the wearer unrestricted freedom of movement during a limited time.

The former class may, in the language of the French Committee of 1882, be termed "fixed" appliances, whilst the latter are "portable"; and this classification fits in with the above-mentioned grouping arranged by Mayer.

1. RESPIRATORY APPARATUS.

The earliest examples of this class were primitive, consisting of a sponge or pad steeped in vinegar or chemical reagents, and held against the mouth or nostrils. To this category belonged the Robert respirator, in which the air inhaled by the wearer was drawn in through a sponge soaked in milk of lime, and enclosed in a perforated case of sheet metal.

All respirators of this kind exert merely a cooling action, and cannot be used for more than very short periods at a time; but they formerly enjoyed extensive employment on account of their simplicity and cheapness.

2. APPARATUS WITH AIR-SUPPLY PIPES.

In these the air required for respiration is drawn through pipes connected with a reliable source of pure air. They

may be divided into suction and compression apparatus. To the first division belongs the earliest type of this class, namely, the nose mask of Pilatre de Rozier, in which air was drawn into the nostrils through a pipe 80 to 100 feet in length, whilst the expired air was discharged through the mouth into the open. Another example was the Brasse apparatus, fitted with respiration valves; as well as a great improvement on the above-named mask, *viz.*, Loeb's patent respirator, in which both inhalation and expiration were effected through a valve box, the expired air being also utilised, on occasion, to blow a signal whistle. These two last-named types could not be used with safety at a greater distance than 100 feet from the source of the air supply.

Of the compressed-air type of apparatus, generally based on the principle of the diver's helmet, there are a number of examples, mostly intended for firemen's use, only a few having found any extensive employment in mines. Among the latter are the smoke helmet made by L. von Bremen & Co. (Plate I., Fig. 1; Fig. 3 shows a low pressure apparatus, and Fig. 4 a high pressure one made by this firm); the many forms of Denayrouze-Rouquayrol apparatus described in various text-books, and still used in a few French and Belgian pits; the Müller smoke mask; and the Stolz mask for rescue work. The Denayrouze-Rouquayrol apparatus has often been used for diving in flooded shafts, whilst the Von Bremen helmet rendered excellent service in the recovery work after the pit fires at the Wilhelm shaft of the Kaiser Ferdinand's Nordbahn Colliery (Ostrau) and Count Lairisch's collieries at Karwin, the Müller mask being also advantageously used in the last-named pit.

(*a*) *The Bremen Smoke Helmet.*

(Plate I., Fig. 1).

This helmet, originally designed for firemen's use, was modified to suit the different conditions prevailing in pit work, where the question is rather to afford protection to the wearer against irrespirable air or explosive gases rather than fire.

The hose-pipe, gloves and trousers being dispensed with, there remains the air-tight and waterproof jacket and the light cork helmet, in which the air supplied from the pump, by way of the air-pipe, is distributed and circulated through conduits so as to impinge on the wearer's face and on the interior of the glass window. The air-pipe from the helmet is attached to the main supply pipe, which is passed through an eyelet on the jacket, near the belt, so that no difficulty is experienced in drawing it along as the wearer advances. When necessary, the jacket is fitted with a safety lamp, fed with air through a branch pipe leading from the neck of the helmet, the lamp being either carried in the hand or hung on a hook on the breast of the jacket. It will burn in any atmosphere, and when not in use can be disconnected with its feed-pipe, the screw socket on the helmet being covered by a cap. At the present time these lamps are generally replaced by electric accumulator lamps.

The complete outfit consists of the air-tight, waterproof jacket of double cloth, fastened round the wrists by straps and round the body by a waist-belt; a light, staunch, cork helmet fitted with screw connections and pipes for the air supply and lamp, at the neck; five 20-metre (65½ feet) lengths of flexible air-pipe; a double-action lever air pump, with duplicate fittings; a safety lamp with extra fittings; a feed-pipe for the lamp, and a set of spanners. The price of the outfit is 1,140 marks (= shillings), packed, lamp extra.

The apparatus may be used for distances up to 200 metres (218 yards), the price being increased by six shillings per metre for the additional piping required. Where there is any existing installation of compressed-air pipes in the mine, the flexible pipe may be coupled to this source of supply and the air-pump dispensed with, thus saving the expense (260 marks) of the latter.

(b) *The Müller Smoke Helmet.*

This helmet is made of good deerskin, and is the same shape as a fireman's helmet, with a lower padded rim that fits on the shoulders. It is fixed in position by two spiral springs fastened on the back of the rim and passed under the arms to hook on to two chains attached to the front of the rim—the apparatus being thus enabled to fit all figures. A double plate of wire gauze with 140 meshes per square centimetre covers the wearer's face and permits the escape of the exhaled air, enabling the wearer to see and hear, whilst at the same time protecting the face against explosions and flame. Behind the gauze is a hollow metallic shell, to which the flexible rubber air-supply pipe is attached.

Air is supplied either from an ordinary portable pump —in which case the makers (O. Neupert's Successor) supply a connecting piece—or else by the maker's double-action 8-inch air pump, which is mounted in an iron case; and, measuring only 9½ by 21½ inches, and weighing only 44 lb., is portable and easy to manage.

The following precautions should be taken to ensure the efficient action of the smoke mask:—

1. The air-pump must be placed where the air is free from smoke. Two men are required to work it, one relieving another as soon as the latter is tired; this is particularly necessary with bellows-pumps, these requiring to be worked

at a quick rate to keep up a continuous and sufficient supply of air.

(2) The mask must be fitted on the wearer by an attendant, at the air-pump station.

(3) The wearer must not start on his journey until he finds the air is coming in from the pump; and the men at the pump must not cease pumping until the wearer of the mask has returned to the station.

The great advantage of the Müller smoke helmet over all other protective appliances is that, being simple in construction, it is not liable to break easily or soon get out of order; moreover, it weighs only about 5½ lb., and the mode of attachment allows the wearer free use of his head and arms without tiring him during his task.

The method of using this helmet in a pit fire will be evident from the following sketch of recovery work after a fire in the lignite district of North-West Bohemia (Plate II., Fig. 1).

On the occasion referred to, a smell of fire (spontaneous) was detected at the right wall of one of the headings. Two manual pumps, supplied with water in special tubs drawn along a chain haulage incline, were set to work, and a cutting was driven in the said wall for a distance of 29 yards through the coal, to the seat of the outbreak. There being no means of supplying fresh air to this cutting, it became necessary to protect the workmen by fitting them with smoke helmets; that is to say, only one man at a time was set to work, cutting and extinguishing the glowing coal, and he was provided with a helmet. As soon as the seat of the outbreak had been detected, another cutting was driven into the coal; but, as this was on the fresh air side, no helmets were needed here.

To supply air to the helmet one of the water-pumps was stopped, and, after being connected up with the air-supply

pipe of the helmet, was used as an air-pump, its position being selected so that the out draught of vitiated air, carbon monoxide and steam passed away freely in the opposite direction, and that a supply of pure air was available for the pump and its attendants. In the drawing (Plate II., Fig. 1), a = the position of the air-pump, and b_1 that of the water-pumps before the cuttings were driven through, their position afterwards being at b_2. In other words, the pumps were situated in the line of the fresh ventilating current and in front of the respective cuttings. By this means the workmen could have performed their task for hours in a continuous supply of fresh air, were it not that the heat given off by the burning coal was too great (above 150° F.) and could not be reduced by more than a few degrees even by constant pumping. Nevertheless they could work for periods of thirty to forty-five minutes without over-fatigue, and each man after coming off duty and taking a little solid and liquid refreshment, was ready to return and resume his task. Consequently the work could be carried on with greater security than if other workmen less acquainted with the situation had had to be called in to help. Under these conditions only a small staff is required to perform tasks dangerous to life and limb; whereas, formerly, the number ranged from twenty to fifty and even more (according to the distance of the fire), carrying material of various kinds for the erection of dams; but they could only work for a few minutes at a time and were quickly obliged to return to the fresh air zone. Notwithstanding the use of mouth sponges, etc., cases of poisoning by carbon monoxide frequently occurred, so that the men were obliged to confine their operations to damming back the fire, and it was but seldom that they were able to get at the fire and quench it with water.

A smoke mask of sheepskin with leather fastening straps and 20 metres of wired rubber pipe fitted with an intermedi-

ate piece for attachment to the portable pump, costs 55s.; with a bellows pump, but without the intermediate piece, the price is 90s. If made of deerskin, with chains and spiral spring fastenings, 40 metres of piping, and intermediate connecting piece, the mask costs 130s. Without the intermediate piece, but with a pump the price is 170s., each extra 20-metre length of rubber pipe being charged 30s. for thin, and 40s. for thick piping.

(c) *The Stolz Rescue Mask.*

(Plate I., Fig. 5).

This consists of a thin sheet-brass face mask, with eye holes covered with wire gauze, and is lined round the edge with a band of rubber so as to make an air tight contact with the face. The air-supply pipes enter at each side of the mask and pass round to the back of the head where they unite. For short distances (up to 110 yards), the bellows pump supplies enough air for two men, and two masks can be connected to the pump, but when the distance is greater only a single worker can be kept properly supplied with air.

Experiments made in the Gerhard pit near Saarbrücken[1] demonstrated the efficacy of the mask. The pump can be easily worked by two men. The drawback to this apparatus, however, is that the length of pipe that can be served, and therefore the distance the wearer can penetrate into the irrespirable zone, is limited. Experience shows that when the length of air-pipe exceeds about 220 yards, the pump is no longer able to supply a sufficient volume of air; and, moreover, the difficulty of transporting the apparatus in the mine becomes too great.

The advantage of appliances with air supply pipes over

[1] *Zeitschrift für Berg- Hütten- und Salinen-Wesen*, 1898, vol. xlvi., p. 129.

the "pneumatophor" is that, where the former can be employed at all, their use is illimitable in point of time, and that they enable the wearers to communicate by word of mouth. The Stolz mask is made by K. Schramm.

3. RESERVOIR APPARATUS.

In these the wearer carries a supply of air in a reservoir slung on his back. To this class belong the two high-pressure apparatus of Combes and Kraft, as well as the Fayol apparatus, which allows the exhaled air to escape direct into the atmosphere, and the well-known Galibert bag wherein the exhaled air is returned to the reservoir. There are also several other forms in which the vitiated air is re-purified by absorbing the carbon dioxide in milk of lime or caustic alkali (soda or potash), such as the Barton, the Schulz apparatus and others, none of which, however, except that of Galibert, have made any headway for use in mines. The second type of reservoir apparatus, with means for regenerating the exhaled air, forms a transition stage leading up to the final group of respiration appliances, namely, the various

4. OXYGEN APPARATUS

with regenerative appliances. To this group belong the apparatus of Schwann, Fleuss, and the more recent Walcher-Gärtner "pneumatophor" and the Neupert apparatus.

When it is a question of affording prompt aid to the injured after a pit fire or explosion, or to quickly repair damaged air tubbing, etc., without danger to the workers, an oxygen apparatus, affording freedom of movement for a limited period is the most suitable appliance to use; and in fact, from the miner's point of view, these are really the only true rescue apparatus; the best, however, being such as

are found reliable for prolonged use, whilst still allowing a maximum freedom of movement to the wearers, and most suitable for prompt rescue operations by reason of their simplicity of construction and easy manipulation.

It is evident that the oxygen apparatus, fitted with means for regenerating the vitiated air and replacing the oxygen consumed in breathing, is the sole type that can be considered; and the construction of these apparatus is necessarily based on the physiological principles of the human body.

In the operation of breathing, one-third of the oxygen inhaled is consumed in the lungs and converted into carbon dioxide, which is then exhaled together with the residual oxygen and the nitrogen in the original air, the latter constituent playing no active part in the process. The volume of air respired by a healthy man is from 305 to 490 cubic inches per minute, the consumption of oxygen in the same period ranging from about 18 cubic inches, when the muscles are at rest, to about 67 cubic inches when work is being done. The volume of carbon dioxide, of course, varies between corresponding limits, increasing proportionately with the consumption of oxygen, the average increase of the latter being 0·183 cubic inch per *kilogrammetre* of work done, whilst the corresponding output of carbon dioxide is 0·17 cubic inch. In order that respiration may be at all possible the percentage of carbon dioxide in the air should not exceed 7·5 per cent., because at this degree of concentration no further evolution of this gas can occur even though an excess of oxygen be present. Even when the air contains 6 per cent. of carbon dioxide, breathing becomes laboured, fainting ensues, and muscular weakness sets in. Hence if one desires to remain for some time in an apartment filled with irrespirable gases, it is not sufficient merely to have plenty of oxygen at disposal—since only about 4 per cent. of the total oxygen

present is consumed at all, and there is consequently a great waste of this gas when the exhaled air is discharged in the open—but, to prevent loss of oxygen, a vessel must be provided, into which the air ejected from the lungs is discharged, and which is provided with means for ensuring the absorption of the carbon dioxide as completely as possible, and so preventing its accumulation in the air to be breathed.

The working life of an apparatus constructed for this purpose consequently depends not only on the available supply of oxygen, but also to a very considerable extent on the amount and continued activity of the absorbent employed to take up the carbon dioxide.

The nitrogen, originally present in the apparatus and the lungs, remains invariable and unaltered, and repeats the cycle of exhalation, regeneration and re-inhalation after an addition of oxygen; so that when this last-named addition is suitably regulated the wearer of the apparatus is supplied with air of normal character, so long as the store of oxygen lasts and the absorbent remains active. Besides, there would be no danger in the total absence of nitrogen, experience having shown that pure oxygen can be breathed without injury even for prolonged periods.

To regenerate the vitiated air exhaled by the wearer, *i.e.*, to free it from the accompanying carbon dioxide and water vapour, various absorbents are employed, with regard to which the following remarks are made by J. Mayer, the originator of the Neupert apparatus[1]:—

"The absorbents available for selection to use in the Neupert apparatus were: potassium hydroxide (caustic potash, KHO), sodium hydroxide (caustic soda, $NaHO$) and soda-lime, a mixture of calcium oxide and sodium hydroxide ($CaO + NaHO$). The two first-named are obtainable in

[1] *Oesterreichische Zeitschrift für Berg- und Hütten-Wesen*, vol. xlvi., (1898).

sticks, presenting a large surface for the absorption of CO_2, whilst soda-lime is granular and porous, and is, therefore, also suitable for absorbing the gas in question.

"The use of solid absorbents (caustic potash or soda) affords the great advantage of preventing perspiration on the face enclosed in the mask, and also of keeping down the temperature in that part of the apparatus, both these absorbents taking up water with avidity and thus drying the surrounding atmosphere. The exhaled air, which is comparatively warm and laden with water vapour, loses part of its moisture by condensation on contact with the cooler air in the mask, this physical process disengaging heat and raising the temperature within the mask until it attains the same degree as that of the exhaled air. Now, these solid absorbents take up the water vapour from the air, before it has had time to condense and contribute to the said heightening of temperature.

"When soda-lime is used as the absorbent, *e.g.*, in the Walcher-Gärtner apparatus, it can only take up CO_2, leaving the water vapour unabsorbed; the latter then condenses and produces a continued rise in temperature, the result of which is that the wearer of the apparatus perspires to such an extent that, in a short time, the apparatus becomes insupportable, especially when a face mask is used. An attempt was therefore made to alter the Walcher-Gärtner apparatus so as to reduce the number of the appurtenances (nose clamp, smoke goggles and mouth pipe) by substituting therefor a kind of mask. Nevertheless, owing chiefly to the unnatural liberation of heat and the perspiration consequent on the use of this absorbent, this attempt had to be abandoned.

"The absorbents employed develop a somewhat considerable amount of heat on taking up moisture at the outset; very little of this heat, however, is imparted to the surround-

ing air, which remains temperate by reason of the removal of its moisture. In one experiment, for example, the air in the bag, after a lapse of one hour from the start, measured 31° C. (87·8° F.), whilst the temperature of the absorbent was 57° C. (134·6° F.).

"Which of these solid absorbents is the best may be gathered from the following considerations: From the purely chemical standpoint preference should be given to the absorbent taking up the largest quantity of CO_2 per unit of weight. Now, caustic potash (KHO), in absorbing CO_2, forms, in accordance with the equation $2\ KHO + CO_2 = K_2CO_3 + H_2O$, potassium carbonate and water. The formation of 1 molecule (44 parts by weight, *viz.*, $12 + (16 \times 2)$) requires 2 molecules of KHO, *i.e.*, 112 parts by weight $(39 + 16 + 1)_2$. When caustic soda (NaHO) is used, 80 parts by weight are required, calcium hydroxide ($CaOH_2O$) requires 74 parts, and calcium oxide (quicklime, CaO) only 56 parts to absorb the same quantity of CO_2.

"Quicklime (CaO) and slaked lime ($CaOH_2O$) would therefore appear to be the best absorbents; but they cannot well be used in the pulverulent form, on account of the readiness with which they become disseminated in the air and are inhaled therewith. Moreover, when dissolved, they no longer present a sufficiently large surface to the CO_2 to be absorbed. With regard to the mixture known as soda-lime (CaO + NaHO), which is obtainable as porous granules about the size of peas, and which in point of chemical efficiency is about intermediate between its constituent oxides, the experiments showed it unsuitable, owing, on the one hand, to the dust given off through the mutual friction of the granules, necessitating the introduction of a plug of wadding in the inhaling tube, which wadding soon become clogged; and, on the other hand, because soda-lime is a slow absorbent of moisture, and therefore cannot keep the air cool and

prevent perspiration. An attempt was made to improve this absorbent by mixing with it an equal weight of the highly hygroscopic substance, calcium chloride ($CaCl_2$), but had to be abandoned owing to the increased weight of absorbent then required and the persistence of the objectionable dust.

"As already stated, 112 parts of KHO and only 80 parts of NaHO are needed to absorb the same quantity of CO_2. Consequently it would not be difficult to choose between them when it is remembered that the last-named is also the cheaper. However, another factor has to be considered, namely, the intensity of the reaction, *i.e.*, the relative rapidity of absorption, a property dependent on the thermochemical qualities and not on the molecular composition of these substances. Now the heat of the reaction during absorption of water is less in the case of NaHO than with KHO, from which it may be concluded that the former is the less energetic of the two.

"Both absorbents were submitted to practical tests, and preference was finally accorded to KHO, which substance has also been recommended by Dr. Heller, chief physician at the Caisson Works at Nussdorf."

That *the employment of pure oxygen in respiration apparatus has no injurious effect on the human organism* has been confirmed not only by physiologists, but also by numerous practical experiments with such apparatus.

On this point Dr. Gustav Gaertner, Regius Professor of Experimental Pathology at Vienna, writes as follows:—

"According to medical experience, the inhalation of undiluted oxygen cannot injure the human organism; on the contrary, it is refreshing and quickening in its action. I have superintended some hundreds of oxygen inhalations for healing sufferers from diseases of the lungs, heart and nerves, and have myself repeatedly inhaled pure oxygen—

on four occasions from the Walcher-Gärtner pneumatophor (once for fifty-five consecutive minutes) — without ever observing any symptom that could be taken to indicate injury to the organism."

Furthermore, it is indisputable that *pure oxygen is the most effective means of restoring consciousness to sufferers stupefied by after-damp.* Although in many cases the patient does not recover consciousness immediately, the oxygen succeeds in driving the greater portion of the carbon monoxide out of the blood within a few minutes, and renders recovery possible. Dr. Haldane found in *post-mortem* examination that, although unconsciousness must have very quickly supervened in the victim, a certain interval—generally about thirty minutes to an hour—ensues before carbon monoxide poisoning is followed by death, and that recovery may ensue if there is any means at hand for supplying the sufferer with fresh air during that period. Without doubt, the immediate use of modern oxygen apparatus by experienced persons, also provided with portable electric lamps, would result in the rescue of a majority of the victims of after-damp following a mine explosion.

The excellent revivifying action of oxygen was demonstrated in the case of a man who was brought to bank in an insensible condition after the fire at the Shamrock pit (Westphalia) on 19th June, 1897. After direct inhalation from a Von Walcher oxygen bottle, the sufferer soon opened his eyes and recovered.

THE SCHWANN RESPIRATORY APPARATUS.

This apparatus, also known as the "Aerophor," consists of a flat elastic reservoir filled with air at ordinary pressure and carried on the wearer's chest; the dimensions need not

be any greater than necessary to hold enough air for a single breath. The air is inhaled through a mouthpiece fitted with a suction valve, and the nose is held in a clamp.

A second valve is provided for the passage of the exhaled air, which is conducted through a tube into a knapsack reservoir on the wearer's back, this receptacle being charged with slaked lime impregnated with caustic soda for absorbing the carbon dioxide. In connection with the lime reservoir are two sheet metal cylinders, containing oxygen under a pressure of 4 to 6 atmospheres and supplying this oxygen to the air reservoir, through a reducing valve, along with the returned air from the lime receptacle, so that the air in the front reservoir is maintained in an approximately normal condition. Demanet reports having used this apparatus for two or three consecutive hours without inconvenience. The apparatus was exhibited by the inventor before the Belgian Academy of Science as far back as 1854, and it was also shown at the Hygienic Exhibition in Brussels in 1876, and the Paris Universal Exposition in 1878, two forms—an air and oxygen regenerator respectively—being exhibited on the latter occasion. Nevertheless, neither this apparatus or the similar one brought out by Dr. Regnard has ever made any headway in practice—at anyrate for miners' use—probably owing to its great weight and numerous faulty details. Be this as it may, Schwann must undoubtedly be credited as the inventor of the first regenerative oxygen apparatus.

THE FLEUSS RESPIRATORY APPARATUS.

(Plate II., Figs. 2 to 8.)

This apparatus, invented by Henry Albert Fleuss of London, is, like that of Schwann, of the knapsack type. From the mask (Figs. 2 and 3), which fits tightly over the

face and is provided with two glazed eyeholes, branch two flexible pipes, *A* and *B*, for the inhaled and discharged air. *A* is fitted with a suction valve and debouches into the elastic air bag (Fig. 8), which is carried on the wearer's chest, whilst the discharge pipe, *B*, contains a pressure valve, and leads into the regenerator, *D* (Figs. 4 and 6). The latter is of sheet metal, with a vulcanite lining, its internal arrangement being, as shown in Fig. 7, namely, divided by partitions, *E*, and the false bottom, *F*, into several compartments, which are charged with alternate layers of caustic soda and hemp. Attached to the bottom of the regenerator is the oxygen reservoir, *C*, from which the oxygen is delivered through the pipe, *H* (Figs. 4, 5, and 6), and mixes with the regenerated air at *h*, the mixture being kept under control by means of the reducing valve, *J* (Figs. 4, 5, and 6), which is adjustable by hand. The mixture of air and oxygen then returns to the air bag. In its original form the apparatus weighed about 31 lb. without lamp. The latter, which was based on the principle of the Drummond lime light, proved altogether unsuitable.[1]

The Fleuss apparatus has been repeatedly used for mining work, among other occasions after the fire-damp explosion at the Seaham Colliery on 8th September, 1880, and at the Killingworth pit in 1882, where a collapse of the shaft destroyed the air tubbing, whilst the men were at work. Extensive experiments were made with this apparatus in Germany, at the Maybach pit (Saarbrücken) in 1885, but proved unsatisfactory, and led to a complete modification of the apparatus, the regenerator being further subdivided by means of a number of perforated metal partitions to separate the layers of tow and caustic soda, and facilitate

[1] The problem of lighting for rescue work and work in smoke fumes has now been solved by the employment of electric accumulator lamps.

charging. This was done because experience with the older form showed that after being in use a short time the absorbed moisture caused the soda and tow to mutually adhere and occasion great difficulty in breathing. In the altered form the regenerator was made to open from the rear instead of at the top, thus rendering the interior more accessible in all its parts. The oxygen reservoir was put in direct connection with the air bag, and the ordinary rubber pipe was replaced by one with a coiled wire lining, to prevent kinking. In addition, the old mask was discarded and replaced by a smaller one, which did not require to be so tightly fixed, the very tight straps of the older form having been found to produce headache after a very short time. The regenerator was surrounded on all sides (except that next the wearer's back) by a water jacket for cooling the air in the vessel. It has also been proposed to charge this cooling jacket (which holds about $1\frac{3}{4}$ pints) with diluted vinegar, wine, black coffee, or other refreshing liquids, which could be administered to the injured in the mine through a pipe provided for the purpose and closed by a tap. Thus modified, the apparatus behaved well under the tests imposed, the wearer being able to work with it for two hours at a time; the weight, however, is not reduced by the alterations.

THE IMPROVED WALCHER-GÄRTNER PNEUMATOPHOR.

(Plate II., Fig. 9).

There are two forms of this apparatus made :—

(*a*) The single bottle form.
(*b*) The two bottle form.

(*a*) *The Single Bottle Apparatus.*

This consists of:—

1. The air-bag, A, with loofah-fibre pads.
2. The oxygen bottle, S_2.
3. The alkali receptacle, L.
4. The nose clamp, N.
5. The packing wallet.

With regard to (1) the *air-bag*, A, is made of gas-tight material and measures 18 inches in width by 22 inches long. It is provided inside with two pads of loofah-fibre for absorbing the alkali. Midway along the upper edge of the bag is the inhaling tube, R, with its mouthpiece, M, of hard or soft rubber, the tube being unprovided with any valve. Near by is a short rubber neck through which extends the screw capsule and spindle s of the alkali apparatus.

On the right-hand side of the air-bag is a slit, S, through which the alkali receptacle and the oxygen bottle can be inserted into the bag, and by means of which the bag can be turned inside out for washing after use. It is fitted with two locking clamps, V, which, when closed, form a gas-tight joint and at the same time grip the neck of the oxygen bottle, the valve wheel r of which projects outside the bag.

Removable suspenders, T_1, are attached to the centre and right hand corner of the bag top, and cross over the shoulders, pass under the arms, and fasten on the chest by hooks and eyes. A supplementary band, T_2, which connects the two suspenders across the wearer's back, serves to carry the bag before the suspenders are fastened.

2. *The oxygen bottle*, S_2:—This is a weldless steel flask tested to 250 atmospheres pressure, and holding 0·06 litre (0·013 gall.). The volume of oxygen it will contain at 100 atmosphere pressure is 60 litres.

On the neck of the bottle is placed the valve, the effluent aperture of which carries a small tube, *h*, with a lateral opening directed towards the centre of the bottom of the alkali receptacle, in order to prevent any spraying of the alkali on the side of the bag under the impact of the jet of oxygen. The valve is governed by a hand wheel, *r*, outside the bag, and before use is fastened by a seal, it being important to keep the valve properly closed. To increase the area of absorption, both the oxygen bottle and the alkali receptacle are covered with cloth. The bottle is inserted into the bag, through the aforesaid slit, S_1, in such a manner that the end fits in a sling, *b*, of the alkali apparatus; that the effluent pipe, *h*, points upwards, with its aperture directed towards the bottom of the alkali receptacle; and that the neck of the bottle fits in the jaws formed by the locking clamps, *V*.

The alkali receptacle, *L*, is a perforated sheet metal cylinder containing a glass bottle filled with 425 cubic *centimetres* of 40 per cent. caustic soda lye and closed by a caoutchouc stopper. It measures 8 inches in length by 3¼ inches width across the base. Between the bottle and the cylinder is an iron ring, to which is attached a sleeve, perpendicular to the longitudinal axis of the vessel and serving as nut for the screw spindle, *s*. The alkali receptacle is placed in such a position within the bag that this sleeve projects through a suitable neck at the upper edge of the bag, a wire being wound round the neck to make the joint gas-tight. The hand wheel of the screw spindle is thus outside the bag and is fixed in a suitable manner, to prevent its being turned at the wrong time. By turning the spindle within the sleeve, the spindle presses on the glass bottle in the alkali receptacle, by means of an interposed rivetted metal plate, and breaks the glass completely, thus liberating the alkali.

A rubber ring and cardboard disc protect the glass bottle

from contact with the metal. The entire alkali apparatus is enclosed in washed cloth, free from dressing, both to increase the surface of absorption and to retain the fragments of broken glass. At the neck end of the alkali apparatus is a sling, *b*, into which fits the butt end of the underlying oxygen bottle.

4. *The nose clamp*, *N*, is a simple spring clutch, the cheeks of which are covered over with soft leather. It is attached to the inhaling tube by a cord or chain ; and two are supplied with each apparatus.

5. *The wallet* is in two parts, an inner and an outer one (the wallet proper). The former consists of a rectangular piece of stuff, in which the folded-up apparatus is enclosed (by folding the edges over), in order to keep out dust and air. A sealed paper band surrounds this package, which cannot be opened until the band is broken. In folding up the apparatus the parts are so arranged that the upper edge of the air bag (with mouthpiece and screw spindle of the alkali apparatus) are at the top of the wallet. When packed the parcel measures about $15 \times 11 \times 4$ inches. For the apparatus stored in rescue stations near or in the mine the wallet may be replaced by an ordinary bag.

Instructions for Using the Pneumatophor.

The apparatus is put together in four stages :—

1. Removal of the wallet and wrapper.
2. Hanging the bag in position and gripping the mouthpiece between the teeth or lips.
3. Breaking the caustic soda bottle.
4. Opening the oxygen bottle and fixing the nose clamp.

The wallet is opened by unbuckling the strap, tearing the paper band and removing the inner wrapper.

In hanging the apparatus on the wearer, care must be

taken that the locking clamp, *V*, and the oxygen valve, *r*, are on the right-hand side. The back band, T_2, of the suspenders is placed over the neck, and the mouthpiece is taken in the mouth. In case of danger a little oxygen is then let out of the bottle; otherwise the suspenders are first laid over the shoulders, passed forward under the arms and connected on the chest, underneath the apparatus. At the outset the mouthpiece need not be gripped by the teeth, but merely held between the lips.

As soon as the apparatus is in position the alkali bottle is broken by turning the screw spindle to the right, with the right hand; an audible crash and the sense of touch will show when breakage occurs. The liberated alkali then escapes and moistens the loofah pads. *N.B.*—The bag must never be laid or held in such a position that the alkali can run into the mouthpiece, or its caustic action will injure the wearer when breathing.

As the supply of alkali is necessarily plentiful, in order to facilitate respiration, some of the liquid will be sure to run down into the lower part of the bag. It may, however, be easily redistributed over the pads by lifting the lower end of the bag sideways.

Previous to the admission of oxygen into the bag, air must be inhaled through the nose; but as soon as the oxygen is turned on, the nose clamp is put in position, and respiration is thenceforward effected through the mouthpiece alone. To open the oxygen bottle, the valve wheel, *r*, is grasped in the right hand and turned towards the rear, the oxygen bottle being meanwhile held in the left hand to assist the operation, as the first turn is rather stiff owing to the necessity of keeping the valve tight when not in use. The gas is admitted in 10-20 small portions, and the valve need not afterwards be screwed up so tightly as before. The bag must not be too fully inflated or difficult breathing will result. The escape of

oxygen from the bottle is revealed by the hissing sound of the jet, and when this is no longer audible it may be concluded that the supply is exhausted.

The Apparatus in Use.—As already stated, the inhalation of oxygen from the bag is effected through the inhaling tube; and breathing should be performed as quietly as possible. Only a small portion of the oxygen taken into the lungs during a breath is actually consumed there, and the expired air, therefore, consists of about 4 per cent. of carbon dioxide and about 96 per cent. of oxygen. The CO_2 is absorbed by the alkali impregnating the loofah pads, whilst the oxygen is again inhaled, which procedure accounts for the long time the apparatus can be used with only a comparatively small quantity of oxygen—at least eight hours when the bearer is at rest or moving about gently; whereas if he is doing work the oxygen supply will be consumed in about half an hour. After being in use some time the bag should be lifted repeatedly in order to mix the contained air and cause the excess of alkali to flow on to the loofah pads.

Uses of the Apparatus.—It is designed as a self-rescue apparatus for miners, and owing to its light weight (10 lb.) it can be taken down into the mine every day unless storage in an underground depôt is preferred. For rescue parties the pneumatophor is naturally an appliance of great value, since it not only enables them to enter foul air but also to perform such tasks as repairs to ventilating tubbing and the like therein. The conjoint use of electric miners' lamps greatly increases the utility of the apparatus. Where smoke fumes are present, goggles should be worn.

Training and Exercising in the use of the Pneumatophor.—Though the apparatus is so easy to manipulate, an occasional exercise in the use of the same appears necessary, so that there may be no mistakes made when an emergency arises for its practical application. This training may be carried on

by the aid of an exercising apparatus, so constructed that all the parts and functions of the real apparatus are clearly defined, though the alkali receptacle does not contain any glass bottle, and the smash of the broken glass is imitated by means of a spring device. The oxygen bottle is replaced by a dummy of wood or iron, the valve being connected to a flexible pipe supplying fresh air, so that when the valve is opened the inrush of air to the bag imitates the hissing of the oxygen jet. In the absence of a compressed air supply the air bag may be connected to a bellows or air pump. The exercising air-bag is provided with a large slit so that the wearer breathes from and into the open air all the while. The men should be exercised in the following details:—

1. Unpacking and fixing the apparatus in position for use.

2. Breaking the alkali bottle.

3. Admitting oxygen (compressed air), and fixing the mouthpiece and nose clamp in place.

4. Inhaling and expelling air through the mouthpiece, particular stress being laid on quiet, regular breathing.

5. The periodical tilting of the bag for the space of several breaths, in order to mix the contained air.

6. Periodical re-opening of the oxygen bottle. When describing the apparatus in general, attention should be directed to the protection of the seals.

Taking to Pieces and Resetting the Apparatus ready for Use.

Taking to Pieces.—After use the apparatus should be washed as soon as possible; and in any case it should be quickly immersed in a large vessel of water, or filled with water through the mouthpiece, in order to dissolve the alkali carbonate and residual caustic alkali. Before washing, the following points must be attended to:—

1. Removing the suspenders, $T_{1,2}$, and the nose clamp, N.

2. Loosening the cord or wire used to tighten the screw sleeve, s, of the alkali apparatus, and taking out the screw spindle.

3. Unscrewing the locking clamp, V, and removing the oxygen bottle S_2. The cloth covering of the bottle should be washed or renewed.

4. Plunging the bag, A, into water or repeatedly filling it with water, to rinse out the alkali—the human epidermis and textile fabrics being readily attacked by this latter ingredient.

5. Removing the alkali apparatus, L, opening the same at the bottom in order to clear out the coarse splinters of glass, and repeatedly swilling it with water to carry away the numerous finer fragments. To loosen the rubber stopper and re-cover it for use over again, the neck of the glass bottle must be broken—an operation requiring caution.

6. Taking out the loofah pads and turning the air-bag inside out, the inhaling pipe being first drawn through the slit. The smooth inner surface of the bag is then rinsed with water and thoroughly cleansed from alkali by wet sponging. The pads are well rinsed with water and then immersed in clean water for several hours, after which they may be dried ready for use over again.

Re-setting is effected in the following order:—

1. The bag being thoroughly dry inside and out, the loofah pads are replaced so as to take up a position below the oxygen bottle.

2. The next step is to insert the alkali apparatus, L, and the oxygen bottle, S_2. The metallic vessel to hold the alkali is charged with the rubber stoppered glass bottle containing 425 cc. of 40 per cent. caustic soda, the bottle being fixed in position by the iron ring and kept out of contact with the metal by means of a rubber band and ring, as well as by a rubber cap slipped over the neck of the bottle; and a disc

of cardboard is set in the bottom. The metal vessel is placed in the small bag and provided with a sling strap which serves to suspend the lower part of the oxygen bottle, the whole being then slipped into the air bag; and the neck, which projects through the short rubber tube, is fastened to the latter by a binding of (preferably waxed) string or brass wire. The spindle, s, is then screwed into the neck and sealed to fix it in the position of repose.

3. Charging the oxygen bottle, S_2. This can be done anywhere, the supply being drawn from large stock cylinders and filled by the aid of the Stohmann apparatus for this purpose; or fresh bottles can be obtained from the makers. The full bottle, S_2, tightly closed, is placed in its cover, which is also intended to absorb a portion of the alkali. The outlet tubes, h, are unscrewed (the opening being turned to face the bottom of the alkali apparatus). The lower portion of the oxygen bottle is next slipped into the sling, b, and the neck is gripped by the bars of the locking device, V, the slit, S_1, being then screwed-to, and the handwheel fixed with a seal.

4. Last of all follow the attachment of the nose-clamps, N, and carrying belts, T_1, $_2$, and the packing of the whole appliance into the wallet or bag.

5. To pack the apparatus up in the wallet it is spread out and laid down, the mouthpiece against the end of the wallet, the locking device on the right. The loofah pads are pushed one over the other; the left side turned over all along; the mouthpiece inserted; the carrying straps arranged and the lower part of the bag turned over the rest. The whole is then wrapped in the cover, surrounded by the paper bands, and placed in the wallet.

(b) *Two Bottle Apparatus* (*Shamrock type*).

(Plate II., Figs. 10, 11 and 12.)

On the invitation of Mining Councillor Behrens, general manager of the Hibernia Mining Company at Herne (Westphalia), Messrs. Waldeck, Wagner and Bender have put on the market a type of rescue apparatus, constructed by G. A. Mayer and particularly adapted for rescue work and other dangerous tasks requiring time for their accomplishment.

This apparatus consists of an air bag with loofah pads, a knapsack, oxygen tube with adjustments, a nose clamp, and wallet.

The air bag.—The bag is provided with two loofah pads, each consisting of four pieces of loofah, for absorbing the alkali.

The knapsack serves to contain two oxygen bottles capable of holding 60 litres (2·1 cubic feet) at 100 atmospheres pressure.

The oxygen tube serves to conduct the oxygen from the steel bottle into the air bag.

The nose clamp is a simple spring clamp.

The wallet serves for the conveyance of the apparatus and its appurtenances, and also contains the alkali bottle, the wrench and the funnel.

Instructions for Use.—The workman who carries the apparatus, and who, in most cases, will be the one to use it, hangs the air bag over his chest in the usual manner, the oxygen apparatus being slung over the shoulders and the two connected by hooks and eyes; the belt, on the other hand, being allowed to hang down loose behind. The knapsack is now turned with its strap side next to the wearer's back and, the lid being turned back, is drawn upwards over the oxygen bag, thus bringing with it the belt attached to

the latter; the lid is then turned up again and the straps are fastened on to the metal buttons provided. In this manner the wallet protects the valves and the alkali bottle which is placed inside the lid. The belt of the wallet is drawn forward and fastened over the air bag in front.

When the wearer arrives at the place infested by the poisonous gases the wallet is removed, the oxygen pipe drawn out of the rubber neck at the top of the air bag; the funnel carried in the side pocket of the wallet is placed in the rubber neck, and the alkali bottle (containing one litre of 40 per cent. caustic soda) is emptied through the funnel into the air bag. Thereupon the oxygen pipe is replaced in the rubber neck and fixed by means of the connections.

All the spanners, etc., for tightening up the various nuts and connections will be found in the wallet. The oxygen supplied is regulated in the same way as in the ordinary pneumatophor. One of the oxygen bottles is fitted with a smooth hand wheel, but that of the other is milled. As the contents of the one bottle must be used up first, say that with the smooth hand wheel, then as soon as this occurs the wearer knows that half of his oxygen supply is consumed, and he is thus enabled to know when to retrace his steps.

G. A. Mayer[1] reports as follows on the employment of the pneumatophor in the rescue work after the fire at the Shamrock Pit (Westphalia): "One section of the pit was opened where the fire was in full swing, and the task to be accomplished was the restriction of the seat of the fire by means of dams. Before this could be done, a partition in a heading driven on the rise had to be removed; but, owing to the preponderance of carbon dioxide in the atmosphere, this heading could not be traversed without the aid of a pneumatophor, nor could it be reached by means of air-pipe apparatus.

[1] Behrens, *Gluckauf*, 1897, No, 49.

Moreover, the temperature was very high in consequence of the fire. By the aid of several pneumatophors, timbers were set up, and finally the partition was removed. In this heavy work and under the high temperature prevailing, the consumption of oxygen per minute was twice the normal amount; so that, even with the double apparatus used, the men could not work more than an hour at a time. The subsequent masonry work and the limitation of the fire to a very small area, were satisfactorily accomplished." Behrens states in the same paper, that however simple and easy to use the apparatus may be, it is indispensable that the men should be trained and accustomed to work with it. The prime essential is that they must accustom themselves to exercise care and economy in using the oxygen supply. Exercise with an apparatus without using oxygen is very useful for learning how to manipulate the apparatus, but practice in breathing with oxygen is absolutely indispensable.

Experiments conducted at the Gerhard and König pits, near Saarbrücken,[1] have fully confirmed the usefulness of the pneumatophor. "While wearing the apparatus the men were able to move about, set up timbers, open and close doors, carry others on their backs, and perform similar tasks without difficulty; and in addition they were able to remain, without inconvenience, for considerable periods in experimental galleries, the air of which was filled with gases rendered irrespirable by burning engine waste and damp shavings. The length of time the apparatus can be used is estimated at between thirty minutes and an hour, a period which in many cases may be extremely valuable for purposes of rescue work. The pneumatophor has this great advantage over other forms of respiratory and rescue apparatus—that

[1] *Zeitschrift für das Berg- Hütten- und Salinen-Wesen*, 1898, vol. xlvi. B, p. 129.

the wearers can go about anywhere with ease, and that it is both easily handled and inexpensive."

Pneumatophors are also in use at the Gottessegen and Deutschland pits in the Königshütte district. A small form is extensively used in the Spanish lead mines, where outbreaks of carbon dioxide often occur so suddenly that the miners have to wear the apparatus continually whilst at work. The self-rescue apparatus (pneumatophor) has also done very satisfactory work in the Vienna Fire Brigade, its principal use being in locating the seat of a fire.

The pneumatophor is also occasionally used at the Archducal Collieries in the Karwin district, in such working places as are dangerous, or where the current conditions of working render quickness of attack imperative, *e.g.*, in cases of sudden outbreaks of gas in the headings, or in opening the valves of flooded pumps. It has also to be repeatedly used in boilers and flues, and under a variety of other conditions.

At the pit fire in the Zollern shaft (Westphalia) on 22nd May, 1898, a rescue corps of seven officials and miners from an adjacent pit, provided with pneumatophors, did yeoman service both in the rescue work and in putting out the fire.

The first cost of a complete outfit of ten sets of the two-bottle apparatus for a mine amounts to about £85, and the annual expenses of maintenance, including renewal of materials and men's time taken up in exercising with the apparatus, are about £35. A single set of the two-bottle apparatus costs £8 10s., but the price of the original type, which is recommended by the inventor where the men are not stationary during the work, is £6. Both forms are supplied by the above-mentioned Viennese firm.

THE NEUPERT RESCUE APPARATUS (THE MAYER-PILAR SYSTEM).

(Plate III. Figs. 1 to 8 inclusive.)

This apparatus, constructed by the firm, O. Neupert's Successor (Vienna), to the designs of Mining Councillor Johann Mayer assisted by J. Pilar, consists—as may be seen from the illustrations on Plate III., Figs. 1 to 8—of an air-bag, AA_1, A_2, of double waterproof material with an opening in the centre (Fig. 2). Above this aperture is placed a smoke helmet with smoke mask (Figs. 4 and 5), the latter being fixed air-tight against the wearer's face by means of a rubber ring, *W* (Fig. 5), which rests against a flexible strip of metal projecting inside the helmet and is covered with a rubber disc, *P* (Fig. 5), open in the centre to enable the wearer to see.

In fitting up the apparatus the mask is first fixed over the face by means of a cross-strap, *R* (Fig. 4), passing over the top of the head and buttoned on to a second strap, *R* (Figs. 4 and 5).

The smoke helmet is then drawn over the head so that one part of the air-bag, AA_1 (Figs. 1, 2, 3 and 7), rests on the chest, the other part, A_2 (Figs. 2, 3 and 7), resting on the shoulders.

Although the mask will act equally well without the smoke helmet, *H*, this latter was chosen because, in case of need, the apparatus is intended to be worn when high temperatures prevail, such as in the case of pit and other fires, under which circumstances the mask alone would not afford sufficient protection against radiant heat. For fire brigade work the helmet and air bag are made of leather ; since it is

necessary to protect the apparatus from direct flame, which the rubber material is unable to withstand. Furthermore, better protection against the intrusion of smoke fumes into the helmet can be afforded by the provision of a waterproof material, covering the neck and aperture, in case an insupportable tightening of the straps should be necessary to make the mask fit perfectly air-tight.

The front part of the air-bag, AA_1, extends about 6 inches below the chin, so that the wearer's chest is left quite free and his power to do work is unrestricted.

The helmet or mask is closed in front of the wearer's face by a glass disc, *S* (Figs. 1, 2, 4 and 7), which—as in the case of electrical miners' lamps—is protected in front by two crossed iron rods, *K* (Figs. 1, 4 and 5). This glass can be opened if necessary. When the apparatus is put on, the glass is left open so long as the wearer is moving in a respirable atmosphere, and is only closed when he enters the zone of smoke fumes, whereupon respiration with the apparatus commences. To enable the moisture settling on the inside of the glass to be removed without opening the latter, a movable pin is fitted in the middle of the disc and carries a small wiper, *i.e.*, a strip of metal covered with doeskin, *O* (Figs. 1, 4, and 5).

Respiration is effected through two sheet metal pipes, *a* and *b* (Figs. 1, 2, 4 and 5), which are fitted with glass or rubber valves and serve to connect the mask with the air bag. The inhaled air is drawn from the one end of the bag, A_1, through the pipe, *b*; the exhaled air flows through the pipe, *a*, into the other division of the bag, *A*. In order to ensure an efficient separation of the inhaled and exhaled air the front portion of the air bag can be divided right up to the top by an internal partition, *mn* (Fig. 1), which, however, is not absolutely necessary, since the apparatus will act satisfactorily without. Furthermore, the sub-division of the air-bag helps

to retard free respiration, since the air is obliged to circulate through the bag.

The oxygen bottle, *B* (Fig. 7) is separately fastened on to a belt by means of a snap hook, and is first suspended over the shoulders, so that it lies on the hip like a soldier's cartridge pouch.

The oxygen bottle is connected with the air bag by means of a flexible rubber pipe, *N* (Figs. 1, 4 and 7), which debouches into the bag close by the air-pipe, A_1. This flexible pipe is generally a fixed part of the apparatus and is attached to the oxygen bottle by a screw connection.

The size of the oxygen bottle varies according to requirements. As a rule it holds 1½ litres of oxygen compressed at 100 atmospheres, but a smaller size (1 litre) may be used for shorter periods, or a larger size (2 litres) when the working periods are longer. Nevertheless it is not advisable to have the oxygen bottles too large, since it is easy to detach the empty bottle, even when the wearer is in an irrespirable atmosphere, and replace it by a full one, which in such event must be kept in readiness. A change can be effected in five seconds, and it is advisable to close the ends of the flexible pipe with the finger until the new bottle is ready to be connected.

If it is found that carrying the oxygen bottle on the hip incommodes the wearer, it can be slung farther round on the back. For the absorption of the exhaled CO_2 and moisture, solid absorbents are used. These are stored in an air-tight glass cylinder and emptied into the front compartment of the bag AA_1 immediately before use. The apparatus can be fixed ready for use in 1½ to 2 minutes.

The admission of oxygen is effected according to requirements in the same manner as in the Walcher-Gärtner or similar apparatus, by loosening the screw, *s* (Fig. 7), the same precautions being necessary. If the valve is adjusted so as to supply a continuous moderate flow of oxygen the

wearer is saved the trouble of periodically opening the valve. This, however, cannot be expected from a wearer unskilled in the use of the apparatus. Attempts have been made to regulate the supply of oxygen by means of a reducing valve; but, so far, this has not been found feasible, except at the expense of unnecessary complications.

For the admission of the absorbents a slit, *U* (Figs. 2, 3, 4, 5, and 6), which can be easily opened and closed by means of two hinged iron bars (Fig. 6) and a thumb screw (Figs. 3, 6 and 7), is provided in the rearward part of the air-bag, A_2. This slit also serves for cleaning out the apparatus after use, the cleaning being best effected by a stream of water from a syringe or the like. This position of the slit at the rear of the air-bag was selected in order to avoid overloading the front portion and disturbing the mask.

Potassium hydroxide (caustic potash = KHO), which is obtainable in sticks, was chosen as the absorbent, its use having been recommended by Dr. Heller. 1·1 lb. of the KHO is used for a two hour shift, *i.e.*, double the theoretical quantity required, this increased amount accelerating absorption and facilitating respiration.

The oxygen consumption proposed is 2½ to 3 times the quantity theoretically necessary; because, notwithstanding care in fixing the mask, waste is inevitable. While the apparatus is in use a certain excess pressure is produced in the mask by the continual supply of oxygen, and it is to this that the comparatively high waste is due, particularly when the supply is not regulated. On the other hand, this excess pressure within the mask, prevents the inflow of smoke fumes or other irrespirable gases in which the apparatus is being worn.

In breathing through the mouth, as in the Walcher-Gärtner apparatus, the oxygen is utilised more economically; but the extra consumption in the Neupert apparatus

RESULTS OF EXPERIMENTS MADE WITH

No.	Date.	Place.	Absorbent.		Duration of Experiment.	Oxygen Consumption.	
			Chemical Composition.	Amount grams.	H. M.	Total litres.	Per hour litres.
1	13/10	Experimental gallery at Wilhelm shaft, in dense smoke. External temperature, 10° C.	KHO	500	1 20	88	66
2	—	Experimental gallery at Wilhelm shaft, in dense smoke. External temperature, 10° C.	KHO	500	1 14	105	85
3	11/11	Experimental gallery at Wilhelm shaft, in dense smoke. External temperature, 9° C.	KHO	500	2 1	142½	71
4	12/11	Experimental gallery at Wilhelm shaft, in dense smoke. External temperature, 0·5° C.	NaHO	500	1 33	139½	90
5	13/11	Laboratory at Wilhelm shaft. Room temperature, 20° C.	NaHO, CaO	500	0 50	61½	74
6	15/11	Laboratory at Wilhelm shaft. Room temperature, 20° C.	$CaCl_2$; CaO, NaHO	250; 250	0 25	30	72
7	15/11	Laboratory at Wilhelm shaft. Room temperature, 20° C.	KHO	500	2 10	147	68
8	10/12	Experimental gallery at Wilhelm shaft, in smoke fumes. Temperature, 1° C.	KHO	500	1 42	100	59
9	10/12	Experimental gallery at Wilhelm shaft, in smoke fumes. Temperature, 1° C.	KHO	500	2 10	82	38
10	10/12	Experimental gallery at Wilhelm shaft, in smoke fumes. Temperature, 1° C.	KHO	500	0 43	—	—

THE NEUPERT RESPIRATORY APPARATUS.

Remarks.
Pressure in oxygen bottle (capacity 1·45 litres) before experiment, 89 atmos.; after, 29 atmos. Most of the absorbent became dissolved.
Similar oxygen bottle; initial pressure 72 atmos. Mask rather leaky, hence the higher oxygen consumption. Breathing unattended with difficulty or perspiration.
Improved mask. No difficulty in breathing. No perspiration. Wearer changed twice; time occupied, 3 minutes. Bag temperature at end of experiment, 25° C.; of absorbent, 38° C.
Greater heat in mask than with KHO, hence higher oxygen consumption. Absorbent remained solid, its final temperature being 57° C. Wearer's pulse at end, 88 per minute.
Cotton wool placed in intake pipe to keep back dust from absorbent, but soon became obstructed, hindered breathing, and induced perspiration. Final temperature of externally unaltered soda lime, 44° C.
The cotton wool in the pipe soon became obstructed, causing laboured breathing and perspiration, so that the experiment had to be quickly abandoned.
Air bag divided in the front to separate inhaled and exhaled air. Final temperature of air bag, 31° C.; of totally liquefied absorbent, 44° C. Analysis of air in bag, CO_2 = 0·1 per cent.; O = 23·7 per cent.
Under official supervision of the Mährisch-Ostrau Mining Board and special committee. Oxygen bottle, 1 C. = 100 CO. Experiment continued till all oxygen exhausted. Breathing easy, no perspiration. Temperature of absorbent several minutes after experiment, 27° C.
Also under official supervision; different apparatus. Low oxygen consumption due to exact regulation of supply and wearer being inactive. 71 CO remained in the 1½ C-bottle. Test discontinued, owing to wearer being too lightly shod to stand the cold in the gallery. No difficulty in breathing, and no perspiration.
Also under official supervision, with a third apparatus, for observing the respiration and the handling of the apparatus. Oxygen bottle 1 litre capacity with 102 CO, only partially consumed.

is readily sacrificed on account of the far greater advantages obtainable.

The weight of the apparatus (smoke helmet, including air bag and connecting pipe) is about 4¾ lb.; the oxygen bottle, containing 1½ litre (150 litres compressed at 100 atmos.), weighs 8·8 lb.; the straps weigh 0·9 lb., so that the total weight is just over 14 lb., or, with 1 lb. of absorbent, about 15 lb. The apparatus is about 5¼ lb. heavier than the Walcher-Gärtner apparatus, though it should be remembered that we have here an oxygen bottle holding 1½ litres, and that the working period is therefore somewhat longer.

By using a 0·6 litre oxygen bottle—which is perfectly admissible, since as already stated the bottle can be changed while the apparatus is in use—the weight can be reduced by nearly 4¼ lb. and the total weight would then be only just over 11 lb. or about 1 lb. heavier than the Walcher-Gärtner apparatus.

The preceding table gives the result of several respiration experiments performed with this apparatus.

Mention may here be made of a statement by Dr. R. Heller[1] who, as already remarked, recommended the use of caustic potash in sticks as an absorbent, and has carried out experiments therewith in the pneumatophor :—

"Hitherto, in an apparatus fitted with fixed masks the wearers have suffered considerably in the face through steam and perspiration, a circumstance attributed to the use of liquid absorbents, in which case the water vapour produced during respiration is increased by that disengaged through the heating of the absorbents. It was hoped that by the use of caustic potash this troublesome water vapour could be abolished—an expectation that was fully realised. Furthermore, the sticks, being readily broken into smaller pieces, offer

[1] *Oesterr. Zeitschr. für Berg- und Hütten-Wesen*, vol. xlvi. (1898), No. 21.

a maximum of surface to the gas. Very frequently the experiments extended for two hours without the slightest formation of drops on the face of the wearer being discernible.

"All the experience gained so far shows that the apparatus most extensively used, whether for working in water or gas, are such as enable respiration to be performed in the normal manner, *i.e.*, through the mouth and nose. The reason for this is, most probably, that breathing with a mouthpiece and nose clamp requires practice, and that persons trying to breathe in this way cannot avoid experiencing a certain disagreeable and anxious feeling. Von Popp, who has had very extensive experience in diving with the East Indian Diving Company, avers that divers who will go to considerable depths when wearing the Siebe apparatus cannot be persuaded to descend to more than slight depths with the Denayrouze-Rouquayrol (mouthpiece and nose clamp) apparatus, notwithstanding its great advantages. By reason of the mask, the Neupert apparatus exhibits the advantage of allowing the breath to be taken freely through the nose and mouth; and, in addition, the eyes are protected from the injurious influence of smoke fumes. In order to convince ourselves whether the apparatus allows perfect freedom of movement a number of tasks were performed, such as carrying individuals, working rotary pumps, etc., whereby we were able to confirm that all work of this kind could be carried out with ease and perfect freedom."

Heller took gas samples from both the Neupert apparatus and the pneumatophor, under identical conditions. In the last-named apparatus a short tube was introduced through the front wall of the air-bag, and through this the samples were taken, partly during inhalation and partly during expiration (the apparatus was the original form of pneumatophor). In both cases the analysis was made with the Orsat apparatus. Comparing the results it may be said that in

the Neupert apparatus the percentage of CO_2 fluctuated, but never exceeded $4\frac{1}{2}$ vol. per cent.; neither did the percentage of CO_2 increase as the experiment progressed, nor were any pathologic phenomena observable. With the pneumatophor the proportion of CO_2 increased with the length of the experiment and attained a maximum of 8·2 per cent. During the experiment fluctuations in the pulse and respiration of the wearer were noticed.

Hence the experiment speaks in favour of the Neupert apparatus; since, even during prolonged respiration, no pathologic phenomena occurred, and consequently the apparatus complies with hygienic requirements. Pulsation curves, taken by means of the Richardson sphygmograph during the use of the Neupert apparatus, are plotted in Heller's paper on exhalation experiments with a Neupert apparatus, published in the *Monatsschrift für Unfallheilkunde* for 1898.

Mining Councillor Behrens, general manager of the Hibernia Mining Company, instituted the following critical comparison between the Neupert apparatus and the pneumatophor.[1]—

"The Neupert apparatus possesses the undoubted superiority over the Walcher pneumatophor that the employment of a mask, leaving mouth, eyes and nose free, does away with the inconveniences attaching to the pneumatophor in connection with the nose clamp and goggles and the necessity for taking the air-pipe in the mouth.

"The Neupert apparatus exhibits the additional advantage of being mounted on the shoulders, and therefore does not impede the wearer's freedom of movement in any imaginable position, to anything like the same extent as occurs with the pneumatophor, which is carried on the chest. It must, however, be mentioned as a disadvantage of the Neupert

[1] *Glückauf*, 1898, No. 22.

apparatus that the air-bag is entirely constructed of rubber, a substance of doubtful durability when exposed to fluctuations of temperature and degrees of moisture in the air; and that the very long seams in the bag are liable to cause leakage, with the material used.

"The principal objection against the safe character of the Neupert apparatus, however, resides in the employment of two valves in the air-pipes. During the experiments in the Shamrock pit the defective action of these valves entirely disabled the apparatus in one case. Since the apparatus can easily get dirty when stored in chambers containing coal dust, the valves (thin mica plates) will undoubtedly be a source of trouble to any one working with the apparatus. Finally, the use of a single oxygen bottle, suspended from a belt at the one side of the wearer, is less favourable than the double bottle fixed on the wearer's back.

"With reference to a combination of the two forms of apparatus, I might suggest that a connection between the Neupert mask and the air-bag by means of a single valveless pipe, would afford the best solution; and also express the hope that both inventors would exert their powers in one direction in order to lead to a perfectly satisfactory solution of this important problem, to the advantage of the mining industry."

Instigated by this critical comparison, Neuperts have latterly modified their apparatus, so that the outer covering of the air-bag is free from rubber and there is no rubber at all in the helmet. Furthermore, they attach great value to the circumstance that the whole of the caustic potash is placed below the air-pipes and not distributed all over the bag, since otherwise the surface of potash exposed is too small in comparison with the volume of air to be treated.

The valves, which, on the occasion of an experiment in Herne (Westphalia), gave rise to the objection that the mica

discs were liable to stick when loaded with condensed moisture and reposing on too large a surface, have now been altered so that the discs rest only on a raised rim 0·5 millimetre thick, instead of on a surface of 3 centimetres, sticking being thus prevented.

In the improved valve (Plate III., Fig. 8) the aperture, *A*, is larger and the mica disc smaller. The valve cover is omitted, and replaced by a couple of crossed brass rods, *KK*, which hold the disc in position and allow a sufficient escape of air. The valves are set in opposite directions in the inlet and outlet pipes.

In this form failure is almost impossible; the plates cannot stick, nor are they quite closed during the passage of the air. Even should the valves not act perfectly, the most that can happen is a disturbance of the air circulation, *i.e.*, the separation of the inhaled and exhaled air—a circumstance which does not destroy the usefulness of the apparatus or involve the slightest danger to the wearer. The same firm also makes an oxygen-filling pump with which the bottles can be filled at 100 atmospheres pressure by hand.

A complete set of the Neupert rescue apparatus, including the oxygen bottle, costs 80 florins (£6 13s.), or 70 florins apiece if ten sets are taken, whilst sets of fifty are supplied at 65 florins (£5 8s.) each. Empty oxygen bottles are exchanged for full ones containing 1½ litres of oxygen at 100 atmospheres pressure for 3·75 florins (6s. 3d.), at Vienna; and a full 10 litre bottle of oxygen at the same pressure is exchanged for an empty bottle against payment of 15·50 florins (25s. 9d.).

V. EXTINGUISHING PIT FIRES.

When the goaf packing is found to grow hot, the tendency may sometimes be successfully combated by cooling the rock with a brisk current of air. For this purpose, connecting ways are driven in the affected section and used for the conveyance of a sufficiently strong current of fresh air. For this method to be successful the heat must, of course, not have attained such a degree that slow decomposition has become actual combustion. In the latter case a current of air would only assist the fire; and, therefore, a converse practice must be adopted and the fire stifled by perfectly air-tight dams or by the means described below.

When a fire has actually broken out, one of the following methods must be resorted to:—

(a) *Chemical Means.*

The methods at one time extensively employed, namely, introduction of steam; compressed carbon dioxide; compressed acid; carbon dioxide produced by burning limestone; as also the introduction of other products of combustion, such as those from coal fires, etc., are nowadays used only on rare occasions.

Mining Councillor Johann Mayer, in his pamphlet on the explosion of fire-damp at the Wilhelm shaft and the resulting fire and recovery work, refers to these remedies as follows:—

"All these methods for quenching and extinguishing fire were known to us; but after mature deliberation were discarded.

"Steam, it is true, increases the volume of the enclosed or introduced air, and, therefore, supplies a relatively smaller quantity of oxygen to the seat of the fire; nevertheless, steam, as such, can only be present in the degree of saturation corresponding to the temperature of the gases. When steam is supplied for a considerable time, the temperature in the burning section must be raised, which is a great disadvantage apart from the fact that, by reason of the resulting currents, it becomes very difficult to entirely exclude air from the seat of the fire.

"If the supply of steam is shut off for a time, the condensation resulting from the lowered temperature produces a vacuum, which unnecessarily causes an inrush of air through all stoppings; and this accession of air at the prevailing high temperature tends rather to feed the fire—which in view of the abundance of fire-damp in the mine would have been highly objectionable in the case under consideration.

"Furthermore, it was found on testing samples of the gaseous products of combustion that, in consequence of the considerable amount of water in the burning section, they were already fully saturated, and consequently any further supply of steam would at best only lead to an increase in volume, owing to the heightened temperature, and, therefore, produce a relatively lower oxygen content in the gas.

"If this heightened temperature is harmless, and no subsequent spontaneous ignition need be dreaded, the advantages of steam are clear. The case, however, was different at the pit in question owing to its fiery character, which was in fact the actual cause of the fire and danger. We were, therefore obliged to endeavour to cool down the seat of the fire and thoroughly exclude access of air in order to arrest the chemical action going on in the interior—an object quickly accomplished by the erection of dams.

"Cooling was to some extent facilitated by introducing

cold water in the ventilating and winding shaft and distributing the same in jets. Broken ice, of which there was a plentiful supply in the late winter months, was also introduced.

"In any case, and apart from any other disadvantages, steam would have been useless under the prevailing conditions, since the fire went out as soon as the site was properly isolated.

"More favourable effects would probably have attended the employment of compressed liquid carbon dioxide (carbonic acid) and compressed sulphurous acid. These gases are already manufactured for other industrial purposes. Their introduction would certainly increase the volume, and reduce the temperature of the gases and thereby quickly put the fire out.

"In using these gases it would be necessary to conduct them direct to the seat of the fire and keep them there, since otherwise air would gain access before the work of isolation had been accomplished, and thus requicken the fire.

"To be successful, cooling must be continued long enough to preclude all danger of spontaneous ignition, a period which no one could properly estimate.

"Apart from the circumstance that it would have been necessary to have the gases in question available as soon as the outbreak occurred (a somewhat difficult matter) the quantities necessary would have been so large as to preclude their employment, on the score of expense alone.

"Furthermore, compressed sulphurous acid is poisonous, and, therefore, undesirable to introduce into the workings, since it would have been necessary to clear them again. On oxidation, sulphurous acid furnishes SO_3, and the resulting decrease in volume produces a vacuum which sets up strong currents of atmospheric air; an objectionable circumstance in view of the fiery nature of the workings in question, seeing

that the danger of a requickening of the fire could not be excluded.

"Even if the seat of the fire could have been completely isolated, in order to prevent access of air during the introduction of gas, the use of this very expensive remedy would not do very much good, the extinction of the fire being certain to follow the erection of dams, without any further measures.

"The introduction of uncompressed carbon dioxide, prepared, for example, by burning limestone, or the introduction of any other products of combustion, would naturally do little good if not harm. With these latter, even in the most favourable cases, the products introduced would contain more oxygen than the gases imprisoned in the burning section, even a few days after the outbreak. In both instances the cooling of the gases previous to their introduction would be desirable and necessary, a condition that would lead to particular complications without any result."

According to C. Demanet, good results have been attained by the employment of specially prepared gases incapable of supporting combustion, large quantities of carbon dioxide being introduced into the pit, and thus removing oxygen from the seat of the fire. The details of this process, which has been used, for example, at the Agrappe Pit, near Mons, are as follows: A coke fire is built near the mouth of the intake shaft, large enough to produce copious volumes of carbon dioxide, the gas being then conducted through a pipe into the shaft, which is closed air-tight at the mouth. If necessary it is cooled by the aid of water jets.

The up-cast shaft is also covered over, but is fitted with a pipe, through which the pit-air, displaced by the generator gases, is able to escape.

The fire is kept up for several days in order to fill the entire pit with carbon dioxide and nitrogen. The attainment of this object can be ascertained by examining the gases

escaping through the upcast shaft. The furnace can then be put out and the pit closed up, so as to leave the fire to cool down quietly by itself.

In Scotland, where this method has also been successfully applied, the carbon dioxide was partly produced by burning limestone, the heated gases from a coke furnace being passed through limekilns, and thereby carrying away the carbon dioxide of the limestone. Concurrently with the introduction of the gas, high-pressure steam, which had been passed through a layer of water and thereby become laden with finely-divided moisture, was blown into the shaft.

(*b*) *Extinction with Water. Dragging Down the Burning Masses and Packing with Clay.*

Occasionally when the fire is of small extent, especially in headings, it can be put out by deluging with water (manual engines), in which case good service is often done by the use of respiration apparatus and electric lamps. Furthermore, glowing masses are often covered up with clay, which prevents the extension of the fire; and dragging down and carrying away the burning mass is particularly effective. In the coal pits of South Hungary, fires in preparatory and step-work headings are extinguished by water (manuals), assisted by the pulling down and removal of the burning mass, and packing the resulting space with clay. In one fire at the Gustav shaft (Anina) in 1893, no less than twelve manuals were required. Where the pit is fitted up with water pipes for keeping down the coal dust, these are extremely useful in case of fire. In order to enable the workers to approach the seat of the fire, a good supply of air must be kept up.

(c) *Insulating the Seat of the Fire by Dams.*

If the fire is not very extensive, and is easily accessible, it can often be quenched in its infancy. Many circumstances, however, may militate against this result. Frequently the fire is accessible from one side only, being unapproachable from the other on account of the smoke and products of combustion. If the fire has already attained any size it can no longer be put out; and it is often difficult or even impossible to set up the pumps in the vicinity of fire or to procure a plentiful supply of water early enough to be of use. Finally, and especially when the workings contain fire-damp, it not infrequently happens that approach to the fire is prevented by the occurrence of explosions. Consequently when the above-named means cannot be used, or have been proved ineffectual, attempts must be made to stifle the fire by excluding air, *i.e.*, by isolating the seat of the fire by means of air-tight dams.

The following appliances, etc., are useful in combating pit fires :—

1. A sufficiently powerful ventilating current.
2. The provision of separate ventilation by means of tubbing and ventilating fans kept in readiness.
3. Filled water buckets with hose and squirts.
4. Tarred canvas sheets.
5. Boards, planks, nails, hammers, etc.
6. Several tubs with clay stopping and plastic clay.
7. A reliable and skilled overman.
8. A selected, healthy working staff sufficiently numerous to admit of frequent changes.
9. Provision of refreshments and restoratives (*e.g.*, black coffee, but no spirits or beer).
10. A stock of respiratory and rescue apparatus.

In the fiery mines of South Hungary, the extremely gassy nature of the coal seams and the overlying clay shales,

coupled with the heavy pressure of the cover rock, renders the work of recovery after fires one of the most exacting and dangerous tasks imposed on the mining industry. It being impossible to review in anything like a comprehensive manner the numerous instances of recovery work occurring within the past century, we must confine ourselves to recapitulating a few of the most important of the precautions generally adopted against these fires, leaving to a later section the question of dam building as practised in the said district.

1. In attacking the fire direct, *i.e.*, endeavouring to extinguish it with water, and at the same time pulling down the burning coal, etc., and packing the resulting hollow spaces—which measures are preparatory to the conclusion of the work of isolating the seat of the fire—a plentiful supply of fresh air, free from fire-damp, must be employed in order to protect the men from troublesome smoke and fumes, and prevent the spontaneous ignition of fire-damp present in the ventilating current.

2. All the materials, boards, clay, etc., necessary for the preliminary recovery work must be kept in readiness at suitable places in the pit.

Each pumping sole should be fitted with a water main provided with screw connections for the attachment of hose pipes and sprinklers to keep down the troublesome and dangerous coal dust, and also for driving ventilating fans in case of need. A water main of this kind greatly facilitates the prompt extinction of an outbreak of fire.

3. Dams built of brick or stone are of no use in pits where the rock pressure is heavy.

Both in such cases and also when the danger of repeated explosions renders it necessary to quickly isolate the seat of the fire, wooden dams, the intermediate spaces of which are packed with clay, act admirably.

No timbers should be left in clay dams. Moreover, since these dams dry in course of time and become leaky, they must then be replaced by masonry dams set up at a distance in the solid rock. Lining the adjacent surface of the headings forms a valuable complement of dam work.

4. Valuable indications of the staunchness of dams are afforded by occasionally reversing the ventilating current.[1]

The dams should be supplemented by employing a current of fresh air to prevent the outflow of depressing smoke-fumes, until such times as a reversal of the current ceases to reveal any further escape of such fumes.

5. Any safety works damaged by explosions must be immediately repaired and strengthened in the intervals—generally short—between successive explosions. In the district referred to, these intervals appear to be never less than half an hour.

6. The greatest danger of spontaneous ignition occurs, not while the fire is being directly attacked, but just before the work of isolation is completed, since, at this latter period, the small amount of air present in the burning section forms explosive mixtures with the fire-damp, and these mixtures are ignited by the fire.

The final work of isolation is most suitably effected by means of a ready-made protecting wall, door or barrier, of wood or iron.

7. The provision of headings surrounding the working sections, and serving as main haulage ways, has been found to answer admirably at the Anina collieries; since the haulage work, pumping and ventilating of the unaffected

[1] At Kladno unsuccessful attempts were made for several weeks to suppress a very strong fire which could only be isolated by two dams. The No. 1 dam in the one heading was got at and closed, but the copious smoke fumes prevented access to the dam in the second heading. However, on slightly opening No. 1 dam and reversing the air current, it soon became possible to close both.

sections of the pit can be carried on through these headings, both during the continuance of the fire and also after its isolation.

When the haulage ways are driven through rock exposed to greater pressure, the cost of driving and maintaining these headings is covered by discarding the older ways and transferring all the haulage to the new headings.

8. When the fire is not very extensive and it is desired to resume working, without waiting for the natural extinction of the fire by isolation, the burning section may be flooded. This treatment, followed by drawing off the flooding water, enables the object in view to be accomplished in a comparatively short time. Flooding the entire mine may be practised as a last resource when all other means prove of non-avail.

Of course, the measures described above may possibly require modification in some respects when applied under different circumstances to those prevailing in the South Hungarian pits.

DAM BUILDING.

Where the coal has a tendency to spontaneous ignition, it is highly advisable to facilitate the erection of fire dams by getting the sites ready beforehand and storing the dams in readiness near by. Previous to building a masonry dam, a temporary one of boards plastered over with mortar may be set up. In Upper Silesia, masonry dams are built 20-33 feet in height, with a thickness of 40 inches at the top and 60 inches at the base, which is sunk a depth of 15 inches in the floor of the gallery. Cross dams are preferably made double, the intermediate space being filled with sand. Cement or hydraulic mortar is used for setting the masonry. To enable the composition of the fire gases to be examined, a pipe is built in the dam and another is provided for draining off any

water that may accumulate. A thermometer is hung on the dam in order to facilitate temperature determinations, and a thin plaster of clay is laid over the surface, so as to reveal any cracks that may form in the masonry.

According to Köhler the preliminary damming of a heading is effected by nailing horizontal, slightly overlapping boards on to uprights and plastering the surface over with lime mortar, this being less liable to crack than clay. Any fissures in the seam must also be filled up; and a hole closed with a wooden plug is bored through the dam. As soon, however, as a fire breaks out a masonry dam is put up.

At the Waldenburg pits, restraining dams to keep back the fire were built of clay, loam or brick-ends. These were followed by double dams, set in recesses 20 inches deep extending all round the roof, walls, and sole of the gallery; the dam nearest the fire being 3 bricks thick and the other 2 bricks thick, while the space between them is filled with sand. At the present time, stone or brick dams (the latter more frequently) are employed in Upper Silesia, the mortar for setting being made of 1 part lime and 3 parts sifted slag from zinc furnaces, or sand—clay mortar being used only in the immediate vicinity of the fire. The surface of the dam is plastered over quite smooth. Similar steps are adopted in the Saarbrücken collieries.

Even when the working section is surrounded by safety pillars, cross dams are often insufficient, and in such event longitudinal dams are built along the face of the surrounding pillars; this is also done when it is desired to isolate the fire from a passage way. In England, it is sometimes the custom to build two parallel dams, leaving an air-way which can be used for traffic and also for drainage. Large dams of this kind are to be found at the Reden colliery, near Saarbrücken, and in Upper Silesia, especially at the König pit. At the latter place, in one seam, a dam, 26-30 feet high, 40

inches thick at the top and 60 inches through at the base, has been built of brick and slag or sand mortar; clay being used where the dam is exposed to the fire. The effect anticipated has not, however, been fulfilled—a prolongation of the dam being necessary.

It is highly advisable to plaster such dams and the coal face smoothly over with mortar, as well as to sprinkle them thoroughly with water. Water under pressure is admitted, for cooling purposes, into the safety pillar; and at the Fanny pit (Upper Silesia), a stratum of air is left for the same purpose between the dam and the face. A Pifé dam set up across the seat of the fire at the Caroline pit (Kattowitz) was found not to answer. Again, at the Morgenroth pit, near Myslowitz (Upper Silesia), the fire broke through, despite the dams, and destroyed the shaft lining and pit head buildings—a similar occurrence also happening at the Skalley shaft of the Königin Luise pit, near Zabrze (Upper Silesia). In Bohemia triple dams have been successfully used to keep back a fire from the unattacked workings.

Very often double dams filled with sand are set up, with an intermediate space only 1 foot through; at the Haith colliery, near Dudley, a space of 40 inches is left.

At the Prinz Schönaich shaft of the Königin Luise pit mentioned above, attempts have been made to construct permanent fire and air dams of old wooden blocks 40 inches long, thickly plastered with mortar, instead of using brickwork. The more tightly these dams are squeezed by roof- or wall-pressure the better they fulfil their purpose; at the same time their erection saves material, time and labour.[1]

The air-lock dams built during the recovery work at Karwin subsequent to the accident of 14th June 1894, will be fully described later on. The idea at first was to close

[1] *Berg und Hüttenmännische Zeitung*, 1894, No. 18.

the galleries provisionally by wooden partitions rendered air-tight by means of felt; but it was soon discovered that carefully erected masonry dams, 12 inches thick, were more convenient and firmer than partitions, besides saving time, and therefore all the temporary dams were made of well-burned bricks set in mortar (one part cement to three parts sand). In addition they were plastered over carefully with cement mortar, and such of them, as were intended to serve as air-locks during the subsequent operations, were provided with solid, planed, single doors and screw fastenings.

"Explosion-proof" dome-shaped dams were made 40-60 inches thick, with the convex side nearest the seat of the fire, and mounted on well-laid cemented masonry, set in recesses in the roof, walls and sole.

The dams used in the lignite mines of North-West Bohemia, which generally have to stand high temperatures, will be described in dealing with the recovery work at the Pluto shafts near Wiesa. In many of the Kladno pits the first dams were made of nothing but two wooden partitions with a filling of rubble. At present, old wooden blocks laid end-on in the gallery are preferred for this purpose. Sometimes the spaces between the blocks are filled with rubble, clay dams being built up at each end to keep the filling in place. These wooden dams, however, are no use when a fire has once broken out, being too liable to take fire themselves; nevertheless they are cheap and easy to set up. More recently the practice has arisen at Kladno, of plastering the masonry dams with a layer of coarse mortar, covered with fine mortar and faced with hot pitch, which makes them exceedingly staunch.

DAM WORK IN THE FIERY PITS OF SOUTHERN HUNGARY.

(Plate V. Figs. 14, 15, 16, 17, 18.)

Three types of dam are in use; cross or transverse dams of clay or masonry, gallery linings and longitudinal dams.

(a) Cross-dams of Clay.

There are two classes of these dams: plaster dams and stop dams.

Plaster dams (Fig. 15) are set up in the galleries when a fire has broken out through explosions of fire-damp or coal dust and where a rapid isolation of the fire is necessary to prevent danger from renewed explosions. The clay is hauled in tubs and formed into balls by hand or filled into iron slings.

Assuming the gallery, *AB* (Fig. 15), containing the brattices, *a* and *b*, has to be shut off from a fire situated towards the right. After removing the rails, the brattice, *b*, is strengthened by the log, *s*, and lateral sprags, *c*, and is then boarded over on the side next the fire, or, when an explosion is dreaded, protected with scantlings. The brattice, *a*, is also covered with boards, and at the same time the space between *a* and *b* is filled with rammed clay. Finally, *a* is strengthened in the same manner as *b*. By means of this kind of dam an outbreak of fire caused by a coal dust explosion at the Ronna shaft, on 20th October, 1894, was successfully isolated in a very short time.

Stop dams are of clay, 3 feet to 33 feet in thickness, and are used at Anina to check the rapid spread of fire pending the erection of masonry dams farther to the rear. They are built in recesses hewn out to a depth of as much as 40 inches all round the gallery and extending the whole length of the dam. The ends are faced with boards or posts.

Where stop dams have to be built in sloping galleries, and

there is danger of an explosion, a protecting wall (Fig. 16) is first set up, about a yard nearer the danger side. This wall is made of log framing, *a*, covered with boards or planks, *b*. A 2½-inch cast iron pipe, *e*, on the sole of the gallery, is carried through the dam and wall in order to prevent any dangerous accumulation of fire-damp behind the wall during the erection of the dam.

These sloping galleries debouch into the main heading of the upper deep workings (Fig. 17) through a vertical cut, *a*, and a cross heading, *b*, since if they opened direct into the main heading the water in the latter would run down into the workings.

To erect a dam in the sloping gallery, the cut, *a*, is shut off by nailing board partitions, *d*, on to the beech or oak log frames, *c*, and the intermediate space is packed with clay. Sometimes, the cross heading is also filled up with clay and shut off by a wooden partition or by the gallery lining, *e*.

(*b*) *Masonry Dams.*

On account of the heavy rock pressure these are seldom used, since they are liable to burst in a very short time, whereas the uniform and gradual pressure merely increases the staunchness of the clay dams. When used, masonry dams are generally made three to six bricks thick.

Portland cement is employed for setting the bricks. These dams are built in recesses cut into the walls of the gallery; and are either solid, to ensure complete isolation, or are pierced by doorways of sufficient size to prevent hindrance to the passage of horses. The doorways are lined with close-fitting oak frames, carrying one or two doors, which merely require shutting to isolate the gallery, the space between them being filled with clay or bricked up, according to the time at disposal. Both clay and masonry dams are luted with wet clay, and the surfaces smoothed over.

Cross dams are often insufficient to isolate the fire, even though the section is surrounded by thick safety pillars, the latter being frequently cracked owing to the heavy pressure from above, or traversed by undetected fissures. In such event, gallery linings and longitudinal dams must be resorted to.

(*a*) *Gallery Linings.*

The simplest form of lining a gallery is by nailing boards on to the existing timbers (about 40 inches apart) so that the walls are covered on both sides (Fig. 17e), the space behind the boards being then packed with clay. These linings, which are employed both in level and sloping galleries, are often more than 100 yards long, and usually terminate in clay dams, as shown in Fig. 16.

Galleries with iron timbering can be isolated in a very effective manner by lining. The elliptical form of iron timbering shown in Fig. 18 has been employed at Anina ever since 1869; and at present nearly 3,000 yards of gallery are timbered with old iron rails weighing about 50 lb. per running yard, bent in the elliptical form. The rails are heated to redness in a furnace and bent to pattern in a machine, each pair being attached by fish plates above and below, and mounted on oak sleepers set in the solid floor. Overlapping oak planks are nailed on to the iron timberings, which are set 2-3 feet apart, an interval of 8-12 inches being left between each pair of planks to allow the creeping rock to make its way through—a precaution of some importance in clay shales. When a gallery timbered in this manner is to be lined on account of fire, a sufficient number of boards, *a*, are slipped into the grooves between the heads and feet of the curved rails, to make a tight lining, the space at the back being rammed full of clay.

(*b*) A longitudinal dam, built in a 16-feet main seam, is

shown in Fig. 14, which at the same time illustrates the method of working pursued in the Anina pits.

Simultaneously with the advance of the double-track longitudinal haulage way, *aa*[1] through the seam, the top lift, *b*, is taken out; and finally, as the bottom lift, *c*, is being worked towards home, the goaf is packed with clay.

By imagining a series of such longitudinal dams, one above another, so that the miner is always standing on clay, an idea will be gained of the typical method adopted at Anina.

WAGNER'S PORTABLE SAFETY DAM.

(Plate IV., Figs. 1-7.)

This dam offers the advantage of enabling all the approaches to the seat of a fire to be closed in a very short time and with a small working staff. Combining as it does, ready portability and lightness with great stability, this dam can be set up very quickly and easily in galleries of any dimensions.

The illustration (Fig. 1) shows the dam extended ready for use. The principal feature of the apparatus is *the bag*, which, when not in use, is folded up in the frame, but for use is blown out in the form of a hollow wall shaped like a mattress, this measuring 13 feet square in the example shown in the drawing. The front and rear walls are connected by a number of bands 14-16 inches long.

The bag is made up of an external layer of very solid, closely woven tissue, carefully coated on the inside with Para rubber and doubled with balloon cloth coated with Para rubber on both sides; this latter tissue, however, is omitted as superfluous in the case of sizes below 8 feet square. Leather eyelets, *o*, are provided at the top, on the front walls of all bags measuring more than 80 inches in height.

The bag is mounted on the *frame*, which is in the form of a box and consists of front and rear walls connected by stay-bolts and covered with sheet iron. It is provided with four legs that can be turned up on their hinges to enable the dam to be carried through narrow headings and doors. The frame also serves to hold the bag when not in use (deflated), and carries on its front face all the necessary fittings, to wit:—

A *large air-cock*, to which is screwed the flexible pipe for inflating the bag; a *small air-cock* with attached *bellows*, the use of which will be apparent later on; the *cap of the deflating aperture*, by means of which the dam can be quickly emptied of air; the *valve*, with its water vessel, the same being a water valve, and consisting of a *U*-tube with a superimposed overflow basin. The ascending limb of the *U*-tube is fitted with a gauge glass, marked by a wire half-way up and by a painted black line 2 inches higher.

The *U*-tube is filled up to the wire mark with water admitted through a small bent tap. When the excess air pressure in the dam reaches $\frac{1}{100}$ atmosphere, the bag is already more than sufficiently inflated, and the water will then have risen as high as the painted mark on the gauge. At an excess pressure of $\frac{1}{50}$ atmosphere, the valve blows off, the ejected water being caught in the overflow basin and returned to the *U*-tube, after the air has escaped, to again act as a seal. The valve thus serves as a pressure gauge and safety valve protecting the apparatus against the consequences of excessive inflation, whether due to inattention in blowing out the bag or to the expansive influence of heat. The water vessel holds enough water to fill the valve three times.

The Stretcher.—The two bars of the stretcher are pushed out against the walls of the gallery, and serve both as struts for the frame and supports for the partly-inflated bag, as shown in the other illustrations.

The *spy-glass* in the front wall coincides with a larger

glass in the rear wall, the two facilitating observation of the state of affairs behind the dam.

Instructions for using the apparatus are given on a tablet attached to the front plate.

The frame also carries four strong leather handles, through which a couple of wooden staves can be inserted, if desired, for carrying the apparatus ; there are likewise eight leather straps for securing the folded bag in the frame, and two cords, the use of which will be described presently.

Other fittings include a couple of ash staves for carrying the dam, fitted with brass hooks at the ends so that they may be used in setting up the larger size dams (over 6 feet high) in position.

When not in use the whole apparatus is enclosed in a sheet-iron case, which is easily put on and taken off, a wire rod and padlock serving to fasten it when required. On the front flap are two bays, one of which receives the large air-cock projecting from the front wall of the frame, whilst the other is closed by a slide on the inner side and serves to contain a wallet, fitted with a repairing outfit and instructions for executing small repairs to the bag. Four iron lugs on the back wall of the case fit into the metal slots on the bearer staves, which are fastened by means of two wire rods and padlocks to prevent their unauthorised removal. All three padlocks work with the same key, and where several sets of apparatus are supplied together one key will do for all.

Fig. 2 shows the apparatus packed up for storage, with the bearer staves fixed at the back. The projecting ends of the stretcher are protected by sleeves. The air-pump shown underneath the package is a strong hand-lever pump of high capacity, able to inflate the bag in a very short space of time. The lever can be turned over to enable the pump to be carried through narrow doors and galleries. Connection between the pump and air-bag is established by flexible wire-lined

hose-pipe of a length suitable to the requirements of each case; experience has shown that the pipe should be at least 50 feet long.

The men should be exercised in the use of this apparatus at least twice a month, in the mine, and properly instructed in cleaning and packing the whole—a set of men from each shift being entrusted with these tasks.

The method of using the apparatus is shown in Figs. 3, 4, 5 and 6. The dam is got ready for use, at the place of storage—a work of only 2-5 minutes—and is carried by two men down into the place where it is to be used, the bearer staves being pushed through the leather handles for this purpose. Two other men follow with the air-pump and piping. The smaller sizes, up to 7 feet square, being light can be carried by one man, and are, therefore, provided with two rings and a belt; in this case three men only are needed.

Arrived at the place where the dam is to be fixed, the staves are removed and the dam set up on its legs in the middle of the gallery (Fig. 4), two of the men lifting the apparatus so that the feet hang down and are fastened by the snap hinges. The bag is then taken out of the frame, the valve charged with water up to the level of the wire, and the pipe ends connected up with the air cock and pump. Air is next blown in until the water rises to the top of the valve glass or the valve blows off, whereupon the pump is stopped, the air-cock is shut and the pipe disconnected, thus leaving the pump and piping free for inflating another dam.

Fig. 5 shows how the partly inflated bag is drawn into position against the walls of the gallery and held there by sliding out the bars of the stretcher.

Fig. 6 shows the bag inflated $\frac{4}{5}$ths, and how the upper edge is directed into the irregularities of the roof timbers by means of the hooks, at the end of the bearer staves, and the eyelets on the bag itself.

After the bag has been laid in position and accommodated itself to the irregular contour of the gallery, the latter will be found perfectly isolated by a rigid wall. Any opening left against the roof timbering must be stopped with clay. When experienced hands are employed, the erection of the dam will be complete in five to ten minutes, at most, after their arrival on the spot. Each dam will effectually close any gallery of smaller sectional area than its own, and will adapt itself to any profile.

When the bag is inflated and the pipe disconnected, one man will be sufficient to attend to the dam. The unavoidable slight porosity of the fabric causes the inflation to gradually diminish, and consequently, when the water level of the gauge has receded to the black mark, the attendant must replenish the air supply with the small hand bellows, and by way of the smaller air-cock, so as to keep the water level between the black mark and the upper edge of the glass. Should the air in the bag become so far expanded by heat that the internal pressure becomes excessive, the valve will blow off, re-closing automatically by the reflux of the water after the surplus air has escaped. This provisional dam can be kept in position for several hours or days, while a solid dam is being erected in front and protected meanwhile from the fire gases. The permanent dam is provided with a tight-fitting door of sufficient size, and, as soon as this is ready, the safety dam can be taken down again, a task requiring the services of two men. To this end the stretcher, rods are pushed in and the cap of the deflating aperture is quickly opened full; the bag collapses immediately and, being rolled up as well as may be, is withdrawn through the dam doors, which are then closed. Thanks to its lightness the recovery of the safety dam can be quickly accomplished, and hence it is never abandoned.

The seat of the fire being thus isolated in one place, the

safety dam can be used in a similar manner elsewhere. To convey it to its new position, or back into storage, the bag is rolled up as evenly and firmly as circumstances permit and is then bound round with the cords already mentioned, so as to prevent it dragging on the ground and suffering damage. The legs are folded up and the bag carried by the staves, pushed through the handles. Before putting away, the dam is carefully cleaned and packed up.

The dam may be carried about above ground without removing the outer metal case, the bearer staves being fixed in position on the rear wall and lifted by two men, while a third folds up the legs and fastens them with the straps provided for that purpose (Fig. 7).

For transport to a distant shaft the staves are removed and the apparatus corded on to a truck, the bearer staves being also fastened on the truck by passing the leg straps through their metal slots and buckling the straps together. The piping and air pump are also carried in the same conveyance.

The price of this dam varies according to the dimensions of the bag, there being eleven different sizes made in single cloth and seventeen in doubled material. The patentee is Richard Wagner of Michalkowitz, Upper Silesia, and the manufacturer Carl Schwanitz.

Experiments with this portable safety dam have been carried out at the Königin Luise pit in Upper Silesia,[1] in an untimbered stenting, 5½ feet square, traversed by a strong draught. The time occupied in fixing up the dam by two men was only 4 minutes 20 seconds. The air pressure in the bag was ½ atmosphere and the cloth fitted tightly on all sides against roof, walls and sole; and could not be dragged away with the hands, even on the application of

[1] *Zeitschrift für Berg-, Hütten-, und Salinen-Wesen*, 1896. B. p. 193.

considerable force. It also withstood considerable counter-pressure. That the air current in the gallery was entirely arrested was conclusively shown by several tests, and the dam was also proved water-tight, the water trickling down the gallery being held back by the bag.

The apparatus consequently fulfilled its purpose of completely preventing the circulation of fire gases through a gallery and thereby enabling a permanent dam to be erected in the rear without danger to the men employed, at least so far as untimbered galleries are concerned; but repeated experiments will be necessary to thoroughly demonstrate its efficacy in timbered headings, especially those in which there is a considerable open space between the timbers and the true walls or roof.

ANALYSES OF FIRE GASES.

(*a*) The gases taken from the draw-off flue at the seat of the fire in the Jacob shaft, after complete isolation had been effected, exhibited the following composition :—

	CO_2	CO	O
on 18th May, 1881 - - -	7·38 per cent.	1·96 per cent.	7·90 per cent.
„ 19th Aug., „ - - -	7·69 „	0·50 „	3·69 „
„ 19th Oct., „ - - -	6·67 „	traces	1·54 „

(*b*) Gases from the isolated seat of the fire at the Herminegild shaft :—

	CO_2	CO	O
on 18th Aug., 1883 - - -	3·5 per cent.	0·5 per cent.	9·0 per cent.
„ 17th Oct., „ - - -	3·5 „	traces	2·5 „
„ 30th Dec., „ - - -	2.85 „	„	2·5 „

These will serve as typical examples of the gases in question.

ISOLATING THE SEAT OF A FIRE WITH DAMS.

According to Demanet, a typical example of this work is furnished by taking the case of a pit served by two headings driven in the same direction from the shaft, and traversing

a series of seams, in one of which a fire may be imagined to have broken out. It may be assumed that, by closing both headings perfectly air-tight in front of this seam, the fire will be stifled for lack of air and by its own products of combustion—the work of coal-getting being transferred to the other parts of the workings until the dams can be reopened.

In connection with such a method of procedure, which is often successfully attempted, there are several important details that need to be enlarged upon.

The task of dam-building in the lower level is generally light, the men being there in a good atmosphere; whilst in the upper level, on the other hand, the task is rendered difficult by the foul and often irrespirable air. In such event, the men must be provided with air by special means, either through tubbings or by the aid of respiratory apparatus such as those already described in previous pages; or, when circumstances permit, by a temporary reversal of the ventilating current. The work of dam-building becomes particularly dangerous where the workings are rich in fire-damp, since, under these conditions, an explosion, before the work is finished, may oftentimes destroy all that has been done and entirely prevent its completion.

When, as in the case under consideration, a section of a mine is to be isolated by building dams in two headings one above the other, the question arises which dam shall be put up first. Experience and theory indicate that when the burning section is one that carries fire-damp, the upper level is the one that should be first shut off. Demanet gives the following particulars of a report drawn up by the experts engaged in extinguishing a fire at the Agrappe colliery (Belgium):—

"When the upcast air-way is closed, the products of combustion are held back and become mixed with the air that

makes its way to the seat of the fire. Concurrently a liberation of fire-damp occurs in the burning section and tends to form explosive mixtures with the incoming air, a tendency, that is, however neutralised by the combustion products, their presence in the proportion of only 10 per cent. being sufficient to prevent explosion. On the other hand, if the intake air-way is closed first and the products of combustion are allowed to escape without restriction, their lightness enables them to disperse readily, whilst the air in the burning section becomes impregnated with fire-damp, and the formation of an explosive mixture becomes inevitable."

The dams are usually formed of tightly-rammed clay, held in place by masonry. They must be provided with a pipe or flue to allow the gases to draw off while the structure is building.

Certain precautions should be observed in finally closing up the dam. For example, as the fire usually continues to burn for some time longer, until the supply of oxygen in the enclosed air is entirely consumed, the resulting gases would exert considerable pressure unless they found some way of escape. On the other hand, any indraught of fresh air, in consequence of the cooling down of the imprisoned atmosphere, must be guarded against, or the fire may revive; and again, as has frequently happened during recovery work in Hungarian collieries, dangerous explosions are liable to occur if the outflowing gases are checked too suddenly.

In Belgian pits the following precautions are adopted: In the upper part of the dam is placed an elbow pipe, which dips into a vessel continuously supplied with water through a pipe fitted with a tap, which is turned on so that the vessel slowly fills with water, the men thus having time to withdraw. By this means the outflow of gas is gradually checked

and finally stopped, in proportion as the pressure of the water column overcomes that of the gas. Subsequently the surplus water merely overflows and runs away, or else the tap is turned off by the men on their return. In addition, this arrangement affords a continuous indication of the progress of the fire, by the volume and nature of the gases escaping from the bent pipe and through the water; and, finally, when the atmosphere in the burning section contracts on cooling, water alone and not air is drawn into the rear of the dam. For this purpose the water tap must, of course, be left open wide enough to supply a sufficiency of water to the vessel.

The dams must not be opened too quickly, even after the fire is believed to be extinct, but must be kept shut for several months at least; since, owing to the entire absence of air circulation and the low conductivity of the rock, the cooling down of the seat of the fire proceeds very slowly indeed, and the coal and rock may continue to glow long after combustion has ceased. Hence the fire may easily break out again as soon as any air is re-admitted.

Air-tight isolation of the burning section is the most practical and convenient means of remedying the evil, since, if the erection of dams is successful, work may be continued in the rest of the pit. Unfortunately, however, this means is frequently either inapplicable or is rendered of no avail by subsequent gas explosions, and in such event there is no alternative but to shut down the entire pit by closing all the shafts.

When it cannot be ascertained with certainty whether the fire is extinct or still in progress, or when there is danger of gas explosions through the revival of the fire by the admission of the air necessary to enable recovery parties to advance direct, the use of "gas-diving" appliances (*e.g.*, such as enable the wearers to move and work in irrespirable gases) becomes

advisable. Should the extinction of the fire by dry methods be found impossible, the extreme measure of flooding the pit is the only means left.

The details of these various plans will now be described :—

Working in Irrespirable Gases ("Gas-Diving.")

Where uncertainty prevails as to the extinction or continued existence of a pit fire, or where the work of direct advance with the assistance of a current of fresh air supplied through brattices, tubbing, etc., would introduce sufficient oxygen to revive the fire and lead to imminent danger of gas explosions, the use of diving gear fitted with air-supply pipes to convey pure air to the wearers becomes advisable.

In this connection, mention should be made of the improved method devised by Johann Mayer, and employed at the Wilhelm shaft (Polnisch-Ostrau) as far back as 1884. For the explanation of this method it will be sufficient to describe part of the recovery work carried on at the Karwin colliery in 1894,[1] the procedure followed in the 4th level of the deep winding shaft (*a*) being taken as typical of the "horizontal advance," and that in the Franziska shaft (*b*) as representing the "vertical advance".

1. AIR-LOCK WORK (HORIZONTAL ADVANCE) ON THE MAYER SYSTEM, AS PURSUED AT KARWIN IN 1894.

(Plate VI., Figs. 1, 2, 3, 4 and 4_1).

(*a*) The task undertaken was to commence recovery work in the cross-drivage on the 4th level of the deep winding shaft, shut off by the barrier No. 3 (Fig. 1), and to ascertain the best manner of putting up dams to isolate the seat of the explosion and fire in the 19th seam on the said level, such

[1] J. Kohout and J. Pilar, *Oesterr. Zeitschr. für Berg- und Hütten Wesen*, vol. xliii., Nos. 24-31.

dams being an unavoidable preliminary to the recovery of the Franziska shaft, which had been closed at the top as soon as the catastrophe occurred.

The experience previously acquired in the matter of direct advance with the assistance of a ventilating current was so favourable, and all the air analyses so satisfactory (there being only traces of carbon monoxide detectable), that most of the experts engaged in the work anticipated no particular danger in advancing through the fumes, with a brattice and air-current from the main gallery of the 17th seam to the junction with the cross drivage from the 19th seam, and erecting there the four important dams requisite for closing the four openings of the said seam (Nos. 4, 5, 6 and 7), with another to close the cross drivage against the Franziska shaft at the point No. 7a. It was calculated that twelve hours would be sufficient to perform these tasks, the assumption being that no special difficulty would be encountered in recovering the probably damaged cross-drivage junction at the 19th seam.

On the advice of Mining Councillor Mayer, the committee, however, decided to employ respiratory apparatus and proceed on the lines laid down by this authority, the selection being influenced by the following considerations :—

1. The uncertainty as to whether the fire had gone out or was still raging.

2. The fear that the draught, which had latterly been continually increasing, before the erection of the air-door No. 3, might, on the re-opening of this door for the purposes of direct advance to the burning section, convey such a large volume of oxygen to the 19th seam as to increase the danger of subsequent recovery work from the Franziska shaft, apart from the direct risk of explosions through a requickening of the fire.

3. Direct advance would endanger the newly-recovered deep shaft until the dams already built had been rendered explosion-proof by masonry.

4. Behind the newly-bricked dam, No. 3, which measured about 18 inches in thickness and was provided with a wooden door, prevailed a depression equivalent to 25-32 mm. (1-1¼ inches) water-gauge. Had it been possible to drive the deep shaft ventilating fan fast enough to overcome this depression, the dangerous air-current could have been diminished and the risks of the direct advance method reduced. In such event it would then have been necessary to keep good watch over the air supply, to prevent the depression changing to compression and thus causing a flow of fire gases from the burning section and producing a partial vacuum therein. However, the maximum speed of the aforesaid fan, being only 60 revolutions, and the greatest depression 34 mm. (1·34 inch) water-gauge, with a volume of 18 cubic metres (636 cubic feet) of air, no particular reliance could be placed on this means of assistance.

A commencement was made on 16th July. At about 13 feet in front of dam No. 3, a second dam, I_2, provided with a door, was built,[1] the intervening air-way of the 17th seam, being bricked up and fitted with zinc tubbing closed by a slide, in order to allow the accumulation of gas between the two dams to be let out when required. In this manner the first air lock, No. I, was formed.

The doors in both dams of the air-lock (Fig. 2) measured 46 inches high and 26 inches wide. The first door was made plain, but the second was fitted with a glass window, *c*, a water-gauge, *b*, and an aperture for admitting the flexible air-pipe. Both doors were fastened with horizontal screw-bolts.

[1] In each case the first dam built is distinguished by the index figure $_1$ after its serial number, the second dams forming the air-locks being marked $_2$.

There being no compressor at the deep shaft, hand pumps (bellows) supplied by L. von Bremen (*B.* Fig. 2), and O. Neupert (*N.* Fig. 2), had to be used. Of these, the first named had a smaller delivery, but was of stronger construction than the other and did not so easily get out of order. The air supplied by both, however, was sultry and under low pressure (maximum 10 mm.—0·4 inches—mercury gauge), so that the men wearing the apparatus perspired exceedingly.

The work was carried on in three-hour shifts, the men in front of the lock working six hours at a stretch. A second pump was provided as reserve in each case, so that if the working pump got out of order the other could be immediately connected to the air-reservoir, *L*, after closing the corresponding pressure pipe by the valve, *s*, which was of similar construction to the air-valve of an ordinary smithy bellows. While the change was being effected the air supply was kept up by means of the one pump only; but this could not be worked at a higher speed than usual (about forty double strokes per minute), as, when overdriven, these pumps refuse to act.

The Bremen apparatus, which had already been tested on the occasion of the Wilhelm shaft fire, was the system chosen. At first the Neupert mask was distrusted, owing to its inferior ability to exclude fumes when worked under a low pressure of air; but afterwards these masks were used in clearing out the obstructed air conduits of the ventilators at the Carl and Henrietta shafts. An apparatus of this kind, worked with a hand pump, was kept in reserve at the deep shaft to render assistance in case of any accident to those working in the vitiated atmosphere (fire gases).

On the day named, two men wearing the apparatus entered the air-lock, the door, I_2, was closed, the pipe hole and all cracks were luted with clay, and an official was stationed at the window to superintend the work beyond the dam.

After opening the door, I_1, and removing the partition erected in front, the two men visited the cross-drivage and advanced a distance of 20 metres (22 yards) from I_1, where they set up the framework and part of the fittings for the barrier II. This barrier being finished and luted with clay, the first dam, I, was taken down, the slide in the tubbing of the air-way closed, the brattice lengthened, and in front of and at about 3 feet away from the barrier, II, were erected the air-lock dams II_1 and II_2 (the latter 11 feet away), both of them being 12 inches thick and provided with doors. At first an attempt was made to put up a mere barrier instead of the wall II_2, and thus construct a partially wooden dam instead of one of masonry. However, on opening the door II_1 such a strong current of air passed through the leaky barrier II_2 that masonry was found to be essential; and from this point onwards all the dams were bricked. It was also found necessary to always put up the first walls about 30 inches in front of the barrier, since otherwise it would have been impossible to take the latter down afterwards.

The dam IV. was set up close in front of the broken crossing of the cross-drivage from the 19th seam. On the left was the mouth of the drainage level, which at one time had been opened in order to improve the ventilation, but was subsequently stopped up when no longer required. The stopping was found to have been entirely thrown down by the explosion, and the whole of the crossing was strewn with broken timbering and the fall of the upper bank of the 19th seam, to a depth of over 5 foot.

On the morning of the 18th July, the barrier, No. 4, was set up. A dead body, almost destitute of clothing in front, was found at † in the western drainage level. In consequence of the obstruction caused by the fall, that part of the cross-drivage which slopes towards the Franziska shaft and drains water into this shaft, was flooded to a depth of

about 20 inches, though the spot where the body was found had already been re-exposed by the recovery work. It could not be ascertained whether the clothing had been burned, or had rotted by the action of the water. The hand belonging to this body was found at the crossing nearer to No. 4.

Only a few fine globules of coke were found here among the thick incrustation of coal dust; consequently there had been no prolonged action of flame, but enormous explosive force.

Notwithstanding the careful construction and luting of the five barriers at the crossing, Nos. 4, 5, 6, 7 and 7a, a comparatively large volume of air still penetrated to the seat of the fire and a considerable depression (more than 12 in. water-gauge) prevailed in a southerly direction behind No. 7a.

After the removal of these last-named dams, a high compression set in at all the closed shafts, a proof of considerable excess air pressure from the side of the deep shaft workings. On this account all the temporary 12-inch brick walls had to be erected as quickly as possible, a task which was completed by the morning of July 20th. The brattice had to be lengthened up to the crossing, owing to the sultry character of the atmosphere, which was contaminated by the smell of dead bodies.

Whilst, on the one hand, steps were taken to strengthen the dams, Nos. 4, 5, 7 and 7a, the dead body in question was removed in the same manner as the two previous ones. So soon as the barrier, No. 6, was opened, the temporary doors of dam No. 6 were bricked and plastered over. The ventilating fan at the deep shaft was kept running all night at a speed of forty-one revolutions, producing a depression of 18 mm. (0·708 inch).

As the discovery of fuses led to the supposition that caps

and dynamite might be found under the fallen rock, the removal of the coal and rock, where not effected with the hands, was carried on with wooden shovels and cramps ; the work being thus considerably delayed.

To somewhat reduce the high compression of 20 to 30 mm. (0·8 to 1·2 inches) water-gauge, the covering on the Franziska ventilating shaft was raised 4 inches on the morning of July 20th at 10·30 A.M., and the aperture increased to 9 inches at 2 P.M. On this day the final strengthening and repairing of the dams was completed, thus entirely isolating the deep shaft workings from the seat of the fire. All the dams were of well-burned bricks, set in lime mortar strengthened with cement, and were plastered over with cement. In all cases the recesses cut for the dams measured 10 to 12 inches deep on the sole to 2 to 4 inches in the walls and roof, the nature of the rock precluding deeper recesses in view of the haste with which the work had to be performed.

The dimensions of the dams were as follows :—

No. 1. 9·2 feet by 6·5 feet by 0·98 foot with 2·95 feet of extra brickwork.

No. 2. 6·5 feet by 40 inches by 12 inches, with 2·95 feet of extra brickwork.

No. 4. 13 feet long, 9·8 feet high, 5·9 feet thick, and arched in the form of a dome on the side of the fire.

No. 5. 9·8 feet long, 5·25 feet high, and 40 inches thick with a door subsequently bricked up.

No. 7. 9·18 feet long, 4·6 feet high, 40 inches thick.

No. 7a. 9·8 feet long, 8·2 feet high, 12 inches thick, with 5·9 feet of extra brickwork containing a double log door. The intermediate space between the doors was packed with dry-set bricks.

During the whole course of the recovery work at the deep

shaft, gas samples were taken from all the shafts, those at the deep ventilating shaft and subsequently at the Franziska shaft being taken at a depth of 295 feet, whereas at all the other shafts the samples were taken just below the kerb. At the deep ventilating shaft, samples were drawn every hour; at the other shafts once or twice a day, or every three hours whenever considerable fluctuations were observed. Samples were also taken in the pit and tested for fire-damp. The conditions of pressure in the closed shafts were read off every hour from the water-gauge arranged above ground, and recorded.

The work was performed in six-hour shifts, except when disturbance was caused by the presence of carbon monoxide.

(*b*) The recovery of the cross-drivage on the fourth level from the Franziska shaft (see Plate VI., Figures 3, 4 and 4_1) was in principle the same as the work just described.

The air in the respiratory apparatus was supplied by a Burleigh compressor at the pit mouth. At each loading place the branch air-pipes were provided with a throttle valve. The excess pressure of 0·2 atmosphere, measured at the gauge, *m* (Figs. 3, 4 and 4_1) in front of the cylinder, was found sufficient.

The dams in this case were set in cement without the erection of any preliminary barrier, in order to prevent as much as possible any access of air to the burning section.

In front of the buildings at the pit mouth an exhaust was set up, the cone of which was connected with a set of zinc tubbing, 24·8 inches in diameter, leading through the shaft. The ventilating of the space between the shaft and the dams was effected by means of the foregoing and its continuation, namely a horizontal zinc tubbing (Figs. 4 and 4_1) of the above width, the end of which was fitted with a protecting open cap in order to prevent the inadvertent insertion of a safety-lamp in the tubbing (where the velocity of

the air was usually 10 metres (32·8 feet) per second); this was particularly necessary during the time the second (outer) dam door was open.

According to the measurements taken at the first horizontal length of the tubbing at the fourth level, the air supplied per second was as follows :—

At 0·4 inch depression (water-gauge) measured at bank, 52·9 cubic feet.

At 1·57 inch depression (water-gauge) measured at bank, 106 cubic feet.

At 3·54 inch depression (water-gauge) measured at bank, 151·8 cubic feet.

This volume naturally diminished somewhat as work progressed, and proportionately more steam had therefore to be blown in so as to increase the depression. As a rule the exhaust produced a depression of 2 inches measured at bank. In view of greater usefulness later on, the above-named tubbing was, at a distance of 656 feet, replaced by two sets of tubbing, each measuring 12 inches in diameter.

Since a depression of about 1¼ inches prevailed in the rear of the dam door, an air-door was set up in every case a few yards beyond the southern end of the tubbing. This door generally consisted of a partly demolished dam fitted with a regulating slide (Figs. 3 and 4). In this intermediate space the tubbing caused a depression, the extent of which could be regulated in accordance with the depression prevailing to the north of the dam (and varying mainly with fluctuations of the barometer), by opening and closing the slide in the air-door. It could also, when necessary, be regulated by increasing the depression of the exhaust at bank. In the eastern section, where this procedure was reversed and considerable compression, due to the fire gases, prevailed, compressed air was blown into the subsidiary dams to counteract this compression.

A workman was posted at each depression door. The depression in the main dam, however, was never allowed to fall below 10 mm., in order to prevent the outflow of fire-damp, and also to provide for the contingency of assistance being required by the men working in the irrespirable air, the dam in such event being thrown open, and an advance made without apparatus. No case of this kind has yet occurred.

These tasks were performed without any risk of suffocation, because all three men could be observed through the window and assisted at any time. In the second air-dam door the window was made to open, to facilitate communication by means of written messages. In addition, a code of electric lamp signals was arranged. The greatest difficulties and dangers were encountered in the recovery of large falls, along with the continual removal of the accumulated water, which, in some cases, was as much as 40 inches deep, as well as the transport of the dead bodies of men and horses. To prevent any access of air through the water outlet of the air locks, the water conduit was deepened at the second dam, and the opening was hermetically closed by interposing a board, *s*, in the current.

The men wearing the apparatus worked in three-hour shifts, the others working six hours. At the end of their shift, the three men came out of the pit, changed their clothes, and then went down again to act as watchmen at the dams for the remaining three hours. Work was carried on day and night, and refreshments were supplied to the men working in the apparatus.

Owing to the strong smell of sulphuretted hydrogen given off by the discharged water, thorough ventilating of all the recovered galleries, etc., was a matter of great importance.

Removal of dead bodies.—As soon as any bodies were discovered, a corresponding number of coffins were brought

to the dam and taken to the place where the bodies lay. The latter were then sprinkled with lysol, wrapped in carbolised canvas, and laid in the coffins, which were then closed, nailed up and returned to the air-lock. The first, or inner door of the lock, was then closed, the second door opened; and the coffins conveyed, one after the other, to the shaft, in a truck used for hauling wood, and then raised to the pit mouth. Here several hearses were in waiting, and in these the bodies were conveyed to the mortuary chamber, accompanied by a number of miners with lighted lamps. The men wearing the apparatus were provided with rubber gloves for handling the bodies, and there was a plentiful supply of carbol, lysol, and chloride of lime, for properly disinfecting all the surroundings. Furthermore, all the men wearing the apparatus, and the assistants who attended to the air-pipes, used carbolised oil for rubbing over their hands, which they subsequently washed in a solution of lysol.

The disinfection and purification of the workers was superintended by a medical man present at the shaft.

Removal of dead horses.—This was a more difficult matter and was effected in wooden boxes about 9 feet long, mounted on wheels, lined throughout with galvanised iron, and fitted with tightly-closed lids. In the rear of the bodies discovered, an air-lock dam was set up, the previous dam being then demolished, the tubbing extended, all the supplementary doors thrown wide open, and the exhaust ventilator employed to produce a depression of 90 mm. (3·54 inches). The box trucks were tipped up near the body in this strong current of fresh air—the aforesaid disinfectants being used—the horses dragged into the trucks by the aid of forks and cramps, the trucks set upright again, the lids fastened down and the trucks taken up to the mouth. Occasionally, when found between falls, the dead horses had to be carried out in pieces, packed in portable, tightly-closed boxes. The ventila-

tion could be maintained by means of the exhaust up to a distance of about 660 yards from the shaft without difficulty.

2. AIR-LOCK WORK (HORIZONTAL ADVANCE) BY THE MAUERHOFER MODIFIED SYSTEM.

(Plate VI., Figs. 5-11).

On account of local conditions in the recovery work at the Pluto shaft, near Wiesa, (in the North-West Bohemia district) in 1895, Josef Mauerhofer was led to modify in some degree the method employed by Mayer. The following description is taken from Mauerhofer's report of this work:—

"In view of the contingencies likely to occur in the ventilation of the long-closed section containing several centres of fire, the committee decided in favour of working with diving gear without ventilation.

"During the time the air-dams were being erected and other preparations made, barometric pressure readings were taken at regular intervals near the dams. From these it was very soon ascertained with certainty that the very extensive section was perfectly air-tight and properly dammed; since the well-known aneroid fluctuations of tension, which are dependent on the actual atmospheric pressure could be detected with absolute certainty.

"The method of gas-diving with a light respiratory apparatus is the result of long investigation and practical experiment; and, previous to its application, very little of a suitable nature for this purpose was known. The term "rescue apparatus," so often used, is in no way appropriate to the appliances employed, for unfortunately there is, as yet, no appliance for mining work which can really claim this title. In fact, none such exists, since, to be of use, it must be arranged in such a manner as to enable the wearer to remain for some time in irrespirable gases, independent of the surroundings. According to the progressive experience gained,

it seemed probable that such an apparatus could be devised, perhaps with the assistance of an oxygen regenerator. Although the employment of various kinds of apparatus, such as the Fleuss, Duff, Denayrouze, Fayol, Galibert, Rouquayrol, Schwann, Müller, Stolz, and similar systems was already known,[1] these were all far inferior to the Von Bremen diving gear, although most of them could be used for recovery-work, notwithstanding that they did not render the wearer independent of the surroundings. I had occasion to take part in the recovery-work at the Wilhelm shaft (Polnisch Ostrau), which lasted for nine months, and was able, both there and at the recovery-work at Karwin and the Pluto shaft, to convince myself of the usefulness of the Bremen apparatus, and to recognise the improvements made therein in accordance with the steady progress made in the mining industry. For, whereas in the recovery-work at the Wilhelm shaft in 1885, one had to be content with the awkward Rouquairol petroleum lamp, supplied with compressed air, at the present time, reliable electrical accumulator lamps are available.

"As regards the method of supplying air to and using the apparatus, this remains the same as when first employed by Mayer in the recovery-work at the Wilhelm shaft. At Karwin, they used in the horizontal advance, portable hose reels such as were used in the shaft recovery-work at the Wilhelm shaft. A very useful arrangement was employed at Karwin for the use of extra air-pipes in case of need. At the Pluto shaft, where the workings to be traversed were more or less horizontal, I dispensed with this by providing another source of reserve air for cases of necessity. At first we tried electrical lamps with reflectors for illuminating the working spaces, by the aid of large thick sheets of glass set

[1] At that time the pneumatophor of Gärtner and Benda had not yet been invented.

in the air-lock doors, similar to those already used on a smaller scale at the Wilhelm shaft. For this purpose we had at our disposal suitable reflector lamps made by Schuckert, Kremenecky and the Vienna Accumulator Company. This enabled us not only to constantly supervise the men working within the lock, but also to carry out an arranged system of optical signalling. I am of opinion that this method of lighting spaces filled with irrespirable gases, by means of reflected light, will afford valuable aid in similar cases.

"At first I was desirous—taking care of course to properly insulate the conducting wires—to try using the reflectors inside the air-locks, but the results obtained in laboratory experiments at the Wilhelm shaft—which made it appear that the possible occurrence of electrical sparks would be extremely dangerous should the conducting wires become damaged in a fiery atmosphere—led me to abandon my intention.

"The incredibly high temperature (38°-40° C.) believed to exist in the closed workings would have placed great difficulties in the way of those wearing the diving gear; I therefore employed ice coolers—an arrangement which acted extremely well. It may here be remarked that compressed liquid carbon dioxide can be successfully used when the warm weather renders the employment of ice more difficult. Although, it is true, a cooling effect might have been produced by increasing the air current, I considered it desirable to avoid any superfluous supply of oxygen, in view of the exceedingly inflammable nature of the coal.

Owing to the ready affinity of the coal for oxygen, all the oxygen admitted to the closed section of the pit in the air supplied to the apparatus was immediately consumed, without, as the analyses clearly showed, any dangerous gases being produced. When the samples were carefully drawn,

the oxygen content never exceeded 5 per cent., nor did the CO_2 fall below 3 per cent., a composition admittedly devoid of any danger.

"In this place a few remarks on the subject of taking samples of air are appropriate. Towards the end of each working turn the divers took samples of the pit gas by the aid of the well-known iron flasks for this purpose, and these samples were analysed, without delay, at the end of the shift —the newly-acquired Orsat apparatus being employed. On the occasion of my absence for a few days, it was decided to check the home analysis in the fire-damp laboratory at the Dreifaltigkeits shaft (Polnisch-Ostrau). I found in several instances that the above-named percentage of CO_2 was accompanied by an abnormally high proportion of oxygen, so that it was evident, from the analysis, that we had to deal with a gaseous mixture differing from that found by experience to be possible in a thoroughly isolated pit. At first I was inclined to attribute the cause to careless sampling, believing that the air escaping from the sleeves of the diving gear might have been drawn into the bottle held by the wearer. In consequence of this view, greater care was exercised, but, though the oxygen content did fall off to some extent, it still remained disproportionately high; so that finally I was led to believe the peculiarity might be due to differences in temperature. This made it desirable to ascertain whether the admission of the superfluous air escaping from the diving dress could enrich the pit air with oxygen to such an extent as to cause danger of a spontaneous ignition of the coal. We had been in the habit of leaving the sampling flasks within the air-lock until just before the end of the shift and drawing the samples immediately before retiring; the flasks that contained water thereby attaining the high temperature prevailing in the workings. The samples being taken and sent up to the pit-mouth in order to be conveyed to the

laboratory at Polnisch-Ostrau, the gasholder was therefore exposed to the relatively low temperature obtaining above ground, the result being contraction of the contained gas and a consequent influx of fresh air during transit. I have thought it advisable to mention this phenomenon, since probably similar instances may have been noticed elsewhere without any immediate explanation being found."

On 19th February, 1899, the main dam was opened and the recovery begun. The procedure and modifications adapted to suit local circumstances will now be described, with reference to the illustrations displayed in Plate VI., Fig. 5 being an elevation and Fig. 6 a ground plan of the gallery, a portion of which is shown on an enlarged scale in Fig. 7.

In the main, the arrangements were similar to those adopted at the Wilhelm shaft, and more recently at Karwin. In our case the compressed air from the compressors above ground was conducted through a 10-inch pipe to the compensator, K (Figs 5, 6), which at the same time served to remove condensed moisture. This vessel, 64 inches long by 24 inches in diameter, was, at the Pluto shaft, situated about 11 yards behind the outer door, S, of the air lock, and from this point the air was delivered by the pipe, R^1, fitted with a throttle valve, H, through the ice chests, E, E^1, the size of which can be gathered from the sketch. By this means the divers were enabled to bear the high temperature prevailing in the gallery; and in fact the men preferred this part of the work to acting as attendants outside the air-lock. The air, after passing through the regulating valve, R, behind which was placed a spring- and mercury gauge, M, was led through the axes of the hose reels, T, T_1 (Figs. 5, 6, 7), into the reeled hose, S_1, S_2—a third pipe, S_3, to supply air to an extra set of diving gear, being attached to the terminal of the main supply pipe at the branch. These pipes were attached to

the respiratory apparatus in the ordinary manner. The method adopted during the advance and retreat of the divers is well known, the third pipe, S_3, having to be paid out and hauled in by hand, whilst the others are more easily managed by means of the reels. To protect the pipes, and more especially the thinner one belonging to the Neupert apparatus, from damage by dragging along the sole, it was found advisable to lead them over a trestle, *B*, fitted with guide pegs. The dam and scene of operations in the gallery were well lighted by means of electric reflector lamps, *R L*. The air-pipes were passed through holes in the door posts, properly luted with clay each time the pipes were paid out or drawn in. The arrangement for obtaining perfectly gas-tight joints in the outer lock door, *D*, by means of the two screws, *r r*, was the same as that used at Karwin.

At the end of each shift the air in the lock, S S_1, had to be admitted into the gallery in course of recovery, which influx of fresh air was particularly dangerous in view of the high inflammability of the Pluto shaft lignite. As the men can remain at work longer in proportion as the supply of materials for the recovery work is increased, it was found advisable to make the doors, *D* and D^1, large enough to enable the said materials to be passed through on pit tubs; and, the gallery in question being already provided with a tramway, the men were able to push the loaded tubs before them right up to the place where the materials were to be used, a winch set up in the rear of the air lock enabling the empty tubs to be withdrawn without any risk of injuring the air-pipes. In case of the advance being checked by the presence of a train of tubs already in the gallery, the same could also be drawn out by means of the haulage rope, *Z*, worked from outside the air-lock, thus avoiding any strain on the men and consequent damage to the air-pipes.

High-power (16-candle) electric reflector lamps, fed from

accumulators, were used, and a system of lamp signals was devised for communicating with the men working in the gallery. The peep-holes in the outer dam door, *D*, were intentionally made of large dimensions, the work being greatly facilitated by the light admitted thereby. Six Bristol lamps were also in use, one being carried by each diver, one kept alight in reserve within the air-lock, and two set up near the attendants at the hose reels. These are very useful, owing to the escape of foul air into the lock when the divers return thereto, as also when, from any cause, assistance has to be rendered to the divers, for which contingency the second reserve air conduit, *L*, was also provided. Air-tubbings, *WL*, worked by an exhaust, were also provided in sufficient quantity and put in position immediately after the erection of further dams by the divers, exhaust ventilation being then produced by inserting in the rear end of the tubbing a nozzle connected by piping to the reserve air-pipe, *L*. This rapid procedure in ventilating was found necessary owing to the readiness with which the walls of coal caught fire when the insulated galleries were allowed to cool down slowly. To further guard against this contingency, a water hose with attached nozzle was passed in from the water main, *W*. Watchmen were also appointed to prevent outbreaks of fire in the rear of the recovery party, and portable fire-engines of the Weise-Monski pattern, mounted on truck wheels, were stationed at various places in the airway.

The risk of fire was always imminent, and on several occasions outbreaks had to be combatted in the close vicinity of the air-lock masonry, the following instances being of particular difficulty: to save two cross-dams a diagonal isolating wall, *M* (Fig. 8), was built; but shortly afterwards a fire broke out in the opposite walls, *S* and S_1, and walling-off had to be immediately resorted to in order to avert serious

danger. The procedure followed is illustrated in Fig. 8, where m_1 and m_2 are the fire walls, very solidly backed with fireproof materials. Owing to the continued imminence of danger the diagonal dam, *M*, had to be removed and replaced by the cross dams originally planned. The same figure shows how the masonry of the air-lock was proceeded with at this critical point.

Another matter of great difficulty was the erection of the dams (Fig. 11). After the divers had built the wall, *M*, and ventilating was commenced, fire broke out in the walls, *S* and S_1, so that the complicated walls, *m* m_1, had to be constructed in order to properly shut-off the sides of the gallery. In consequence of heavy pressure and permanent danger of fire, the entire south wall of a 100-yard incline into which four galleries opened, had to be isolated in an air-tight manner by means of sand packing and the erection of a solid barrier of masonry, *m* (Figs. 9, 10), a series of pillars, *S*, being built to take part of the strain from the brickwork.

VERTICAL ADVANCE. MAYER SYSTEM.

Plate VII., Figs. 1-8.

Employed in the recovery-work at the Franziska winding shaft, Karwin.

The matter in hand was to isolate the workings appertaining to this shaft—already closed up at the mouth—by the aid of gas-diving apparatus, the first task being to brick up the openings at each level and thus shut off all the workings as though the shaft were a pipe. This being done and the shaft cover removed, the shaft was ventilated by means of exhausts, etc., and the erection of isolating dams was commenced from the loading places by building air-locks, the horizontal galleries in the rear being provided with ventilation, whilst beyond the dam the advance was continued towards the seat of the fire with the aid of respiratory apparatus. The mechanical and other appliances requisite for this

method of recovery and used at the Franziska shaft will now be described.

No compressor for supplying the air to the respiratory apparatus was already on the spot, and though air could have been obtained from the Sommeiler double-cylinder compressor at the Johann shaft, a machine delivering 155 cubic feet at 5 atmos. pressure, yet the distance (over 1,300 yards) would have caused delay and entailed great expense, since nearly 1,000 yards of piping would have to be laid in the ground and the remainder carried on pillars. The idea was therefore abandoned and a Burleigh compressor (Brown's system) was borrowed from the Archduke Albrecht's Hohenegger shaft. The setting up of this compressor, including the building of the foundation, occupied a week. The machine was of the vertical type with a 10-inch steam cylinder and 16¾-inch stroke, the two single-action air cylinders being fitted with pressure valves (one each) below the upper cylinder head, and suction valves in the pistons, admitting air during the down-stroke of the latter, the cylinders being open at the bottom. A second valve in the delivery (compressed air) pipe prevents any retrograde movement of the air. Water is sprayed in through the upper head of the cylinders. The dimensions of the air cylinders are: diameter 12¼ inches; stroke 15 inches; the maximum speed being 60 revolutions, and the normal speed 45 revolutions per minute.

This compressor was worked at a pressure of 4½ atmos., and delivered on the average 88 cubic feet of (absorbed) air per minute. During November the water injector froze and the pipe had therefore to be wrapped in straw bands, a little water being allowed to run through when the engine was at rest, notably on Sundays and holidays, to prevent the pipes freezing up.

The compressed air (tension 4·5 atmos.) was stored in

two reservoirs containing respectively 123 and 342 cubic feet, and conveyed thence through a 2-inch wrought-iron pipe to the second floor of the pithead building (Plate II., Fig. 1). A branch was inserted on the ground floor for connection with the air conduit to be subsequently fitted in the passage way of the shaft, and a second branch at the first floor for supplying air to the reserve storage vessel on the cage. At the second floor, the pipe was fitted with an ordinary throttle valve, *V* (Fig. 7), the air being then conducted through a flexible pipe into the hollow axis of the hose reel, and thence through the flexible pipe wound on the reel and leading down to the cage. The valve, *V*, was worked by hand and served to reduce the pressure from 4½ atmos. to the most desirable pressure (1·1 atmos.) for the length of piping (330 yards) and number of apparatus (3) employed. A gauge, *M*, in front of the valve indicated the pressure in the storage vessel, another, *M*, on the farther side of the valve recording the reduced pressure.

Two mechanics were placed in charge of the throttle valve during the vertical advance in the shaft, each one working three hours at a time, the constant attention required making longer shifts insupportable. Once, at the commencement, one of these attendants unwittingly closed the valve entirely when regulating the pressure, the interruption of the air supply frightening the men below and driving them to the cage for safety. Consequently an automatic valve for reducing the pressure to 1·1 atmos. was devised, but was not completed by the time the shaft work was finished.

At the outset only the smaller air vessel was used, but experiment showed that on stopping the compressor the air pressure receded from 4·5 atmos. to 1 atmos. in 20 minutes when 4 sets of Bremen's apparatus were in use with a 306-yard length of piping, and in 22 minutes with 3 sets of apparatus and 218 yards of piping. As, however, 20 minutes

were required for ascending the shaft from the lowest level to bank, and another 10 minutes had to be allowed for the return journey from the working places to the shaft and for reeling the air-pipes, the air reserve in case of accident to the compressor was considered insufficient, and on this account the larger air-vessel was added, thus affording enough reserve air to last for $1\frac{1}{2}$ hours.

In addition, four air-pumps worked by hand, were placed at *H*, (Fig. 7), to act as a reserve supply in case of damage to the air-pipe or the compressor and reserved storage, though the pressure they were able to produce was but very slight and the air sultry. However, they were never called upon.

The connection, *s*, between the iron air-pipe, and the rotary stuffing box of the central air-inlet to the hose reel, consisted of a length of rubber tubing, to prevent any injury arising from the shifting of the reel. The main flexible air-pipe was securely fastened by copper wire to the grooved end of the gas-pipe projecting from the wooden lagging of the reel, and the length was such that two coils remained still unwound when the men were engaged at the lowest depth (870 feet) in the 20th seam. From the reel the pipe was conducted over a wooden pulley, *f* (Fig. 1), mounted on the head frame, and down through the roof of the cage to a length of gas-pipe fixed in the centre of the cage, to which it was attached by means of two nuts. The gas-pipe was fitted at the bottom with a 3-way tap, the two lateral branches of which were connected to small hose reels, *i. g.* (Figs. 1 and 2) with central air-inlets, and the middle branch to a 66-foot length of piping to supply an attendant who had charge of the signalling, unloading material from the cage, paying out and coiling up the air-pipes for the wearers of the apparatus, and who had no occasion to go far from the shaft. The length of piping wound on the small reels, *i*, *g*, depended on the distance of the working places from the shaft—22, 44

and up to 66 yards long. These small reels were similar in construction to the main reel, the air being introduced through the hollow axes fitted with rotary stuffing boxes. For winding up the short length of piping from the middle branch of the tap, a reel was provided on the wall of the cage.

The piping for this work was supplied by the firm of L. von Bremen, and measured $\frac{4}{5}$ inch in internal diameter, the hard rubber tubing being 0·157 inch thick, strengthened with an inner coil of strong ($\frac{1}{25}$-inch) iron wire, and enclosed in a sheath of hempen cloth. The 20-metre (66 feet) lengths were provided with brass connections, the nuts being fastened in place by wire. This piping costs 6 marks (shillings) per metre (40 inches), and the Bremen apparatus 218 marks, *ex* works, Kiel. (The Neupert smoke mask costs 40 florins (about 66 shillings), and the piping 2 florins (3s. 4d.) per metre, *ex* Vienna.)

The electric cable for signalling between the cage and bank (and *vice versâ*) was conveyed, in the same manner as the air-pipe, from the reel, *O* (Fig. 1), on the opposite side of the pit frame, over the pulley, *p*, and down to the signalling apparatus in the cage. This cable consisted of three insulated tinned-copper wires $\frac{1}{25}$ inch thick, twisted together and covered with two layers of woollen yarn wound in opposite directions, over which was spun an outer covering of flax tape steeped in some kind of composition.

During the ascent and descent of the cage the air-pipe was looked after by five men on the top floor, and the cable by three men. In the former case, one man turned the reel, another attended to the coiling of the pipe, one drew the pipe gently in the direction of movement between the reel and the pulley, one directed it at the edge of the shaft, and the fifth hauled on it in the immediate vicinity of the pulley. At the electric cable, one man worked the reel crank,

another attended to the cable between the reel and the pit-frame, and the third man looked after it near the pulley.

Neither the air-pipe reel nor that of the cable could be fixed in any position; since otherwise the pipe and cable would have been broken when the engine driver released the brakes (according to signal) to lower the cage a little; furthermore, the tension on both pipe and cable had to be kept uniform.

Owing to the size and comparative immobility of the pipe reel, it was sufficient to station a man at the crank in order to turn it when required; but the cable reel, being light and easily rotated, had to be provided with a light-weighted rim brake, which kept it at rest but allowed it to give under a slight pull.

In both winding compartments the mouth of the shaft could be hermetically closed by easily movable sliding doors, *nn* (Fig. 1), the openings left for the winding-rope being packed by a couple of caoutchouc flaps. During the descent of the cage the air-pipe and cable were held by two attendants above the shaft doors, to keep the tension uniform, and attached to the winding-rope by clamps (Fig. 8) at intervals of 130 feet. On the ascent of the cage these two helped to draw up the pipe and cable, and removed the clamps from the rope.

On a given signal the shaft doors were opened or closed by two or three men, so that the shaft was only left open for a few seconds during the passage of the cage.

A reserve of air was kept in the cage, for use in case of any breakage of the piping; and as this reserve is of great importance it will be more closely considered. The arrangement used at the Franziska shaft (Plate VI., Fig. 1) was based on the Brasse regulator, previously in use, which consists of a mouthpiece attached to a double tube about 40 inches long, which terminates in a brass box of about

155 square inches surface and $1\frac{1}{2}$ inches through. The one tube goes down into the lower part of this box, and is there provided with a suction valve which opens during inhalation and closes when air is exhaled from the lungs; and at this end the apparatus is in connection with an inflated bag made of air-tight material. The other tube opens direct into the box, on both walls of which are mounted fine membraneous flaps, which open during the exhalation of air and allow the vitiated air to escape into the irrespirable external atmosphere. The nose has to be held in a clamp to prevent inhalation of fire gases through that organ, so that practice is necessary in using the apparatus.

This regulator can only be used when the air supply is under very low pressure (about 5-10mm. mercury gauge). Hence an air-bag is essential, the higher pressure in the reserve air-vessels in the cage precluding direct connection with the Brasse apparatus. On this account, Pilar recommended the use of a reducing valve; and in the absence of a suitable valve of this kind for bringing down the pressure to about 0·2 atmos., a compromise was arrived at by lowering the air-pressure to 0·5 atmos. through an ordinary automatic reducing valve attached to the reserve air-vessel, and then delivering the air to four Galibert air-bags through a throttle valve, which still further reduced the pressure (to about 0·2 atmos.), these bags being used to supply the Brasse apparatus. In consequence of the unavoidable leakage from the reserve air-vessel and the bags, the pressure in the former had generally sunk from $4\frac{1}{2}$ atmos. to 2 or even $1\frac{1}{2}$ atmos. by the end of a three-hour shift, whilst the air-bags were usually quite empty. Moreover, the entire arrangement, however carefully designed, did not afford sufficient security, the breakage of a horizontal pipe having, on one occasion, endangered the life of a workman. To prevent the recurrence of such an accident, the examination

of the pipes was more strictly performed before each descent, and any suspected lengths were at once changed, the wet horizontal pipes being changed every day and carefully dried before being put in use again.

In consequence of the accident aforesaid and of the insufficient air reserve, the unreliable Brasse apparatus was discarded and replaced by a direct supply. The manner in which this problem was solved is illustrated in Figs. 2, 4, 5, showing the appliance devised by Pilar, which was first used at the Carls shaft, and has proved reliable.

A small opening was made in the neck of the Bremen jacket at *A* (Fig. 4) in which was inserted a kind of nozzle holder. The air escaping from the reserve air-vessel was reduced to a tension of 0·1 atmos. by means of a delicate Salzmann reducing valve, and passed through a vertical pipe into a horizontal one.

Injury to the main pipe being less imminent than to the horizontal pipes, and the reserve air-vessel at the Carls shaft not being of any larger capacity than 22 cubic feet, a branch from the main pipe (Fig. 2) was connected with the horizontal pipe. From the latter were suspended three pipes provided with nozzles, *B*, and taps (Fig. 5) fitting into the nozzle holders in the neck of the jacket. Should the wearer find that he is not receiving any air he returns to the cage, opens the cover of the nozzle holder, *A*, inserts the nozzle, *B*, of one of the pipes, into the opening of the nut, *g*, until the end, *B*, is held by the forked spring, *f*, whereupon he turns on the tap. This last operation may be also effected automatically, or, at least, the tap may be opened about one-third, by means of a sloping pin on the tap. The maximum amount of air passes when the tap is turned two-thirds round, a complete revolution shutting it again. As soon as the man is again certain that he is receiving air, he can, by opening the upper tap, ascertain whether the main pipe is

in order, this being immediately evident by the strong influx of air. The air pressure from the compressor is 1·1 atmos. (measured above at the throttle valve) and a little more than 0·2 atmos. in the loading places down below. If the main pipe is really uninjured, then the air supply coming from the above is alone utilised, and that in the reserved vessel is not drawn upon. On the other hand, should the main pipe be found damaged, the upper tap must be closed again, and the men must use the air from the reserved vessel as economically as possible until drawn up.

It is advisable to insert a light interchangeable sieve of brass gauze in front of the reducing valve to prevent any impurities entering the valve from the air-vessel.

The excellent Salzmann reducing valve (Fig. 3) differs from all other systems—in which stuffing-box friction is inevitable, owing to the use of springs, weights, or membranes—and consists of a vessel filled with mercury in which floats a bell, *b*. This bell adjusts itself automatically on turning a horizontal cone valve, so that it admits the air to its interior at a desired reduced pressure and transmits the same to the air-pipe in the rear of the cone valve. The latter is maintained in position by adjusting the weight on *l*.

The valves are constructed by the maker for use in steam pipes, the above named application of the valve to compressed air at the Carls shaft being the first of its kind. The cost of the valve is 240 marks (shillings) *ex* Leipzig. At the Carls shaft it was found to answer admirably; in one instance all three men made their way out by using the nozzles, *B*, after the breakage of the horizontal pipe. The nozzle can be disconnected by unscrewing the nut, *g*.

With regard to the consumption of air in the apparatus, no special measurements were made, apart from the empirical tests and a few subsequent observations during the horizontal advance. Originally, on the basis of the

experience gained by Mayer at the Wilhelm shaft, the air consumption for three apparatus with a 330-yard length of $\frac{4}{5}$-inch piping was calculated as $3 \times 100 = 300$ litres (106 cubic feet). Owing to the considerable divergencies existing in published data on the consumption of air by workers in mines, the following figures were taken as a basis: An ordinary man, weighing 11 stone, takes into the lungs 550 cc. of air at each inhalation when breathing quietly; as he makes 18 breathings a minute, he therefore consumes in that time 9·9 litres (604 cubic inches) of air. These figures increase when work is being done, but no accurate data are available on this point.

On ascertaining the suffocation point arising through lack of oxygen, without taking into consideration the action of poisonous CO, it may be remarked that a certain amount of air always remains in the lungs, the quantity of this so-called "residual air" being about 1,450 cc. In addition to this there still remains in the lungs, during normal unforced breathing, the amount of air which could have been driven out by a strong expiration immediately after normal breathing, namely, about 1,525 cc., so called "reserve air." The lungs, therefore, contain about 2,975 cc. after an ordinary exhalation, and after an ordinary inhalation about 3,525 cc. of air.

According to experiments conducted with the Brasse-apparatus and Galibert air-bag, somewhat laboured breathing can be kept up for ten minutes. The air consumption per minute, therefore, amounts to 12·6 litres, since the Galibert bag has a capacity of 125·7 litres.

According to our experiments with the air-vessel No. 1, the consumption of air per minute and man, at a pressure of 0·2 atmos., amounts to 15·02 litres with 920 feet of pipe and an internal diameter of $\frac{4}{5}$ths of an inch. The air entering the helmet cools the wearer's face by its sudden expansion,

since it is delivered by two conduits, *I K* (Fig. 4), and an upper one which is in front of the face. All these are modified into three long narrow slits at the point of outlet.

According to the experiment, it may be assumed that no cooling occurs in consequence of reduction of pressure, either in the air-vessel or in the pipes up to the throttle valve, but that any cooling is counterbalanced by the external warmth. The capacity of the vessel is $V = 3{\cdot}5$ cbcm., and the reduction of pressure during 25 minutes (three men wearing the apparatus) was $5{\cdot}5 - 2{\cdot}1$ abs. $= 3{\cdot}4$ atmos. Taking v as the total air consumed, then $v = \frac{3{\cdot}4\ V}{2{\cdot}1} = 5{,}670$ litres, at a pressure of 1·1 atmos., or about 9800 litres of air at 0·2 atmos. pressure, *i.e.*, 150 litres of air of 0·2 atmos. pressure per man and minute, or 15 times as much as is absolutely required for respiration.

The air pressure in the final 20 yards of pipe nearest the mask must amount to 0·2 atmos., as was also confirmed later during the horizontal advance. It is therefore evident that the greater part of the air serves merely for cooling and ventilating the mask.

In working at a distance of more than about 30 yards from the shaft the men carried with them portable Galibert air-bags and Brasse regulators, and laid these ready to hand. This reserve was, however, left untouched, and after the recovery of more than about 20 yards from the shaft it was discarded altogether. The distribution of the staff during this work was as follows: three men wearing the apparatus, one of the three being always an official or supervisor, entered the lower stage of the cage. At each descent the necessary material—wood in lengths not exceeding 8 feet 6 inches and bricks not more than 300 at a time—and sufficient cement mortar to meet current requirements, were taken down in the cage. The latter was enclosed on both the longer sides

with walls of perforated sheet metal, and provided with lattice doors in front and rear. Work was done in the day time alone, there being four shifts in the twelve hours; but, as the time occupied in going up and down the shaft, and overhauling the horizontal line of piping and the apparatus on the cage, took up half an hour at each shift, the net working hours were thus reduced to two and a half per shift.

In addition to the men already mentioned as working the reels and cable, there were stationed in the upper storey of the pithead buildings an official and an overlooker. A telephone communicating with the ventilating shaft was also installed there, to enable a signal to be given for starting the fan at once in cases of imminent danger; also a speaking-tube and signal-striker, worked by a wire-pull, extending from the platform near the pipe-pulley to the engine-room, for communicating with the engine-driver by word of mouth or signal respecting the regulation of the winding speed. To enable the overman to speak with the men on the different floors, a set of holes 40 inches square, one directly above another, was cut in the flooring:

In the upper storey were also two bells; one with a deep tone, sounding every time a signal was given from the cage to bank, or *vice versâ*, and the other, of higher pitch, which rang each time a signal was sent from the pit mouth to the engine-driver. The lower floor (shaft kerb) contained a bell for the shaft and the pushes belonging to the two sets of signals. All signals from the pit or from bank also rang different toned bells in the engine-room; but of all the signals sounded by the deep-toned bell from the pit, the only one the driver had to pay any attention to was the first, *viz.*, "stop!" and he was obliged to wait instructions from the pit mouth before either starting or reversing. These instructions were not given until word had been sent down, from

the top storey to the ground floor, that the men were standing by at the air-pipe and cable.

In addition to the electric signals, an ordinary shaft signalling bell was kept in reserve, the rope-pull for which led down the shaft as far as the fourth level, and was easily accessible from the cage.

On the lower floor of the building there were also stationed an official and an overlooker, who had under their charge a signalman, six hands to work the shaft doors, and two men to regulate the tension on the cable and air-pipe, during the ascent and descent of the cage, and to put on and remove the rope clamps.

Other members of the staff constantly present included a foreman mechanic, to keep in order the whole of the machinery and test the appliances mounted on the cage, and an electrician, who had charge of erecting and repairing the electric signalling apparatus and accumulator lamps.

The lighting of the galleries, etc. containing irrespirable gases, was effected by Bristol accumulator lamps of English make, weighing $4\frac{1}{2}$ lb. each, and giving an average illumination of $2\frac{1}{2}$-3 normal candles for seven to eight consecutive hours. The price of these lamps was 37 florins (about 62 shillings) each.

The following code of signals was drawn up for use during the vertical advance, and arranged to sound in all the storeys of the pit-head building, as well as in the cage and the engine-room :—

.	Stop !
. .	Lower cage a little !
. . .	Raise cage to bank !
. . . .	Short of air !
—	All's well ! (signal from down below that everything is all right).
— —	Acknowledgment of preceding signal,

from bank, or inquiry from bank as to how things are going in the pit.

— . . . . . Signal from bank for the men down below to come up.

. . . . . . Did not understand your signal; repeat!

— — — — — Help required; start ventilating fan!

During the work of installation, the overmen and miners —who volunteered for the task—were exercised in the use of the respiratory apparatus under the foundations of the winding-engine; and thus all the preparations for entering the closed shaft were completed by 24th August, 1894:—

Complete Isolation of the Pit.

When it is found impossible to get near the site of a pit fire without danger, which is more particularly the case when fire-damp explosions simultaneously occur; and when air-tight damming-up is inapplicable or has been rendered useless by fire-damp explosions, then the pit must be completely isolated by covering up all the shafts concerned in the ventilation. To this end a strong platform is constructed a little below the pit mouth and covered over with a layer of clay. These dams must be traversed by pipes, just in the same manner as found necessary in the case of gallery dams.

In almost every instance where complete isolation of the pit is attempted it is successfully accomplished; but this method results in a long delay ere coal-getting can be resumed, since if the pit be reopened too soon the fire readily bursts out afresh and the whole task has to be repeated. Moreover, the method is not universally applicable; sometimes the shaft dams are destroyed by fire-damp explosions; and sometimes the workings communicate with those of an adjacent pit by way of a goaf through which a supply of air makes its way. In the fiery pits of Southern Hungary the work of isolation is performed by setting up log platforms just below bank in all shafts that take any

part in the ventilation of the pit, which platforms are covered over with about 8 feet of clay. When the shafts communicate with drifts, these shaft dams are built a little below the opening of the last named. The intake-pipes of the ventilating shaft are also closed quite air-tight with tamped clay.

Flooding a Burning Section isolated by means of Dams.

The task of flooding a burning section previously isolated by means of dams was successfully practised at the Ronna shaft, Anina (South Hungary), on the occasion of a fire caused by a coal-dust explosion in 1894, it being considered inadvisable, in view of the desired quick recovery of the dead bodies in the isolated section, to wait until the fire had been stifled as a result of the erection of dams.

To retain the water, the following arrangements of dams were devised :—

In Galleries. The erection of dams in galleries is intended to keep back water, either permanently or as a temporary measure. In the latter event an outlet sluice for the water must be provided, but in the former case a pipe is inserted for drawing off water while the dam is building; and is afterwards stopped up.

Dam sites should be selected where the rock is compact and free from breaks or fissures, and the rock must be dressed with mallet and chisel. Where the pressure is slight the dams may be set in recesses, but, when a heavy pressure of water is anticipated, the dams must be dome shaped (convex) and provided with abutments.

If it is found necessary to work on the rear (water) side of the dam, a hole must be left in the masonry and closed only when the dam is completed.

Where the dams are required to remain merely a short time they may be made of pine, otherwise oak and stone must be used. If the water pressure acts perpendicular to

the grain of a wooden dam the latter is termed a balk dam; on the other hand, in a wedge dam, the pressure acts endways of the grain.

WOODEN DAMS.

(a) *Upright Balk Dams.*

(Plate V., Figs. 4 and 5.)

These dams are used in wide low galleries. The face of the rock coming in contact with the ends of the balks is sloped upward with mallet and chisel at an angle of 20° on the water side, the wall surfaces being dressed straight. The depth of dressed surface from front to rear should exceed the thickness of the dam by $\frac{2}{3}$, so that the latter can be forced onwards a little by the water pressure. To enable the dam builders to work at the sole, concrete dams are set up in front and rear between two sets of posts, and the water led away through a gutter. The sloping surfaces in roof and sole are covered with a layer of moss, which in turn is covered by 1-inch willow planks set lengthways of the gallery.

The balks, previously trimmed on three sides and cut exactly to size, are then set up in position, commencing at the sides and working towards the centre, and are fastened to nailed stays on the water face of the dam. The balks nearest the walls are shaped off at the one side so as to leave a space of an inch or so on the front face for the insertion of the luting and wedges, whilst on the rear face they are flush with the walls. The central timbers, after being pushed back a little, are finally drawn forward by means of a bar and winch and held tight until the wedging is completed. This bar carries on its rear end a nut held by means of a clamp, so that when the bar is twisted the nut drops off and the bar can be drawn out. The middle balk

being drawn into position, all the joints between the timbers are calked with oakum or moss, working from the walls and towards the centre, whereupon wedging is commenced from the centre outwards, beginning with flat wedges and finishing with pointed ones, all of hard wood. As a rule a ½-inch pipe is stuck in a hole through one of the balks near the roof, in order to allow the imprisoned air to escape; but this pipe is stopped as soon as it begins to discharge water. Finally, the front face of the dam is backed up with strong props to keep the balks from giving way under the water pressure.

Dams of this kind, measuring about 20 inches through, will stand the pressure of a 260- to 295-foot head of water, which is equivalent to 8 to 9 atmos.

(b) *Horizontal Balk Dams.*

This type of dam is employed where the galleries are high but narrow. The dam is set up against recesses in the walls and is provided, at the dry face, with an upright wall in front of which the balks are laid, their rear ends being calked and wedged. The men working at the rear face of the dam finally make their way out through a manhole, which is then closed and fastened up by a flap door backed by discs of leather.

At the Nouvelle Haye pit, a gallery 56 inches wide and 62 inches high, was isolated by a dam of this kind, composed of three balks measuring 24½ inches by 20½ inches, the boards laid between them being ½ inch thick. The water pressure was equal to a head of 103 feet.

A balk dam fitted with a water door is shown in Plate V., Figs. 6 and 7. A door frame is constructed of strong beams set in a recess, *S*, cut in the solid rock with mallet and chisel, leaving the opening, *f*, free for haulage and other traffic.

Then horizontal blocks, *l*, are laid along the roof and sole, and the upright beams, *s*, are connected with the door head and sill by dovetailing; a strengthening prop, *c*, being also attached to the headpiece. All the timbers in the recess are rendered staunch by wedging or cementing up the joints. The door, *t*, which is formed of two layers of planks set crosswise, moves on hinges and can be shut to after the removal of a short length of rail, *z*. The pressure of the water (coming from the right hand side of Fig. 7) keeps it shut fast. The air hole, *r*, at the top is to allow air to escape from the rear of the dam, and is afterwards closed with a dry plug driven home; and the water-pipe, *w*, near the sole, is fitted with a tap. A drain for the outflowing water is provided in the gallery by laying timbers, *x*, on which are mounted the sleepers and rails, *y*.

(c) *Wedge Dams.*

These dams take the form of a truncated cone with level basal surfaces, and are composed of separate balks, shaped so that their edges, if prolonged, would meet in a point. A dam of this kind acts as a kind of magnified plug driven in between suitably-prepared surfaces in the gallery. These surfaces must be $1\frac{1}{2}$ to 2 times the length of the dam, to allow for the latter being forced onwards by the water pressure. In place of wooden wedge dams, preference is given to dome-shaped dams of masonry which are just as effective and much less difficult of construction.

In the Mansfeld mining district, use has been made of square wedge frames of oak timber, the wedges being formed of pine $24\frac{3}{4}$ inches long, with their sides tapered in such a manner that if prolonged a distance of about 23 feet they would meet in a point. In front of the dam site the gallery

measured 67 inches in height by 49 inches wide, and, in rear of same, 91 inches by 74 inches. The pressure was equal to a head of 72 feet of water, and forced the wedge onwards a distance of 1 inch.

MASONRY DAMS.

Dams constructed of massive masonry offer resistance solely by their own weight, and have therefore to be built up with great care, on which account arched or dome-shaped dams are preferred. They are arranged either as cylindrical dams with two abutments, or as dome-shaped dams with four (see Plate V., Figs. 8 and 9), the latter being the more efficient type.

The material consists of the hardest bricks (clinker bricks) obtainable (or, more rarely, quarried stone), and hydraulic mortar. No manholes or air-pipes are required, the work being commenced at the rear face and continued towards the front. A water-pipe covered with a water-tight lid is required for the subsequent removal of the water behind the dam; but is not closed until the mortar has hardened and the dam thoroughly set.

The preparatory treatment of the dam site is the same as for wedged-shaped dams, the roof and sole being sloped at an angle of 14°. Further security is sometimes afforded by partly replacing the rock with brickwork, or by erecting a water-tight casing of masonry along the gallery on both sides of the dam. In building water-tight dams the work is begun at the bottom and sides, working towards the centre and top, and finishing off against the roof—or better, by corbelling a layer of bricks at the roof and finally closing the hole left below this course. The radius of curvature of bricked dome-shaped dams is generally between 23 and 33 feet, and the thickness of the dam 40 to 60 inches.

EXAMPLES OF CYLINDRICAL AND DOME-SHAPED DAMS.

At the Engelsburg pit a cylindrical dam has been built in a sloping seam (angle of dip 53°), the chord of the dam measuring 8·2 feet, the vertical height 12·4 inches, radius 8·4 feet, with a curve of 4¾ inches per 40 inches of chord (radius 80 inches); and a dome-shaped dam at the Eintracht pit near Steele, the measurements of which are as follows:—Inner chord, 50 inches; curvative, 5·1 inches; radius, 5 feet. At the Samson pit near St. Andreasberg, a volume of water equivalent to a pressure head of 1,312 feet is completely held back by a dam 80 inches thick with a curvature radius of 16·4 feet.

DAM DOORS.

These doors serve to protect the workings from anticipated sudden inrushes of water. Wooden doors in cast-iron frames made in one or two pieces have been used, the frames being chamfered inwards on the side nearest the water. The wooden door, consisting of three layers of 2-inch oak planks set crosswise and protected with metal in a suitable manner, fits into the recess formed by the chamfer, and a water-tight joint is formed between them by means of tarred canvas. When occasion arises these doors are closed and fastened by a couple of screw bolts.

A double-flap wooden dam door, in a wooden frame, has been set up in the Kronprinz Friedrich Wilhelm pit near Saarbrücken. The flaps are made of three layers of 3-inch oak planks covered with strong sheet iron. They meet at an angle of 152° on the side nearest the water. The oaken frame is a little over 2 feet wide, the sides nearest the walls are sloped in the form of a wedge, and are covered all round with a water-tight layer of masonry built against the walls of the gallery. When open, the doorway leaves a free space 7¼ feet wide by 6¼ feet high, so that horse haulage can proceed without hindrance.

More recently, wrought-iron doors set in cast-iron frames have come into use. Those manufactured by Heintzmann and Dreyer of Bochum leave a doorway, 3 feet wide by 5½ feet high, and consist of a sheet-iron plate, 3·6 feet wide by 6 feet high, bent in the form of a cylinder, the convex side being placed nearest the source of (water) pressure. The thickness of plate depends on the amount of pressure anticipated, but is generally about 1·14 inches. The cast-iron frames are set in a bricked dam. The doors are closed by means of screw bolts and a wrought-iron bow, and the joints are tightened by a layer of tarred canvas. When the door is shut, the water-pipe leading through the dam is closed by a slide on the side nearest the shaft, and can easily be reopened when it is desired to let the water run off. These doors can withstand pressures of 11 to 25 atmos.

Figs. 10 and 11 (Plate V.) represent a dome-shaped masonry dam with iron door, *T;* the masonry, *M*, being supported by abutments, *W*, at the roof, sole and sides. The wedge-shaped cast-iron door frame, *R*, is strengthened by ribs, and on this is hinged the dome-shaped door, *T*, of forged boiler plate. The contact surfaces are planed smooth, and the joints are tightened with tarred canvas. Two iron bridge pieces, *b*, resting against the frame, serve, with the screw bolts, *s*, to fasten the door when closed. For single-track horse haulage the doorway is 37 inches wide and 67 inches high, but different sizes are made to suit all requirements.

A locking device for dam doors, constructed by Wenker and Berninghaus for the Karlshütte pit, near Dortmund, is illustrated on Plate V., Figs. 12 and 13. These are made in different sizes, and, being very solid, offer considerable resistance to pressure.

Where, as often happens, for instance in lignite mines, an inrush of quicksand is feared, the dams erected are

arranged in such a manner as to keep back the sand whilst allowing the water to drain away. This is accomplished by building well-propped barriers of strong timbers and planks with a thick backing of straw or pine brushwood, which acts as a filter and allows nothing to pass through but water, which can then easily be kept under by pumping.

For shaft work, balk dams, wedge-shape dams, masonry (cupola arch) dams and concrete stoppings are used.

Flooding the Whole Pit.

When it is found impossible to extinguish a pit fire by the dry method, flooding the entire workings is practised as a last resource. Allowing the natural drainings of the pit to accumulate is generally too slow a process, and must be assisted by introducing large volumes of water from above ground. When the workings have been completely filled, all that is necessary is to pump them clear again to resume coal-getting.

This method is absolutely certain, but its attendant inconveniences are so great that it is not resorted to until all other means have failed. The amount of water required is enormous, and frequently out of all proportion to the available supply; and, on the other hand, if a divertible brook is near the premises, the efficiency of the pumps is far below the task put upon them of clearing the workings in a short space of time. Finally, when the pit is pumped out again it is generally in a very bad condition, owing to falls, etc., so that a pit which has to be flooded is necessarily put out of work for a long time.

In the fiery pits of South Hungary, when flooding is resorted to, the pit water is allowed to accumulate, and all available supplies of water above ground are drained into the workings until it is evident, from the indications of a float placed in the shaft, that the seat of the fire is entirely under

water. Formerly the flooded pit was left alone for a month or six weeks to give the fire time to go out completely, but it was found in many cases that this result occurred at once, although in others the fire broke out again as soon as the pit had been cleared.

Although, *e.g.*, at Anina, the actual flooding takes only two or three weeks, the subsequent recovery of the workings —which are often quite choked up with falls—by the direct advance method, accompanied by ventilation through batteries, tubbing, etc., may occupy as much as a whole year, since it is only in the case of galleries, lined with iron or masonry, which suffer little damage from flooding, that the work is unattended with more than slight difficulty. Accumulations of fire-damp often occurring before the shaft has been fully isolated, and the high temperature (90°-100° F.) in the workings, cause a great deal of trouble and inconvenience, though the recovery-work proceeds under much more favourable conditions, as regards ventilation, when communication has been re-established between two deep levels. In view of this circumstance it is highly important to endeavour to effect this communication at the outset, and the necessary galleries should therefore be lined with iron or masonry. An instance where this procedure proved of great value in recovery-work is afforded by the 1887 fire at the Thinnfeld pit.

VI. RESCUE STATIONS.

(a) *Stations above Ground.*

At the Government collieries in Upper Silesia, ambulance chambers[1] fitted with heating appliances, an operating table, a cupboard containing bandages, water supply and discharge pipes, etc., are erected at each shaft, and each chamber is provided with two stretchers, a hand blower, a reel with about 100 feet of rubber piping, a locked chest containing two Stolz smoke masks, an 8-hour portable accumulator lamp, two safety lamps, an axe, hammer, screw wrenches, chisels and nails. The chests, hose reel and blower are fitted with handles so that they can be lifted from the trucks and carried where required if the tramway does not extend sufficiently far.

At the same pits reed mats have been recently provided for carrying injured miners, both in the workings and above ground. These mats, which are 6 feet long by 40 inches wide, are made of Spanish reeds and tarred hemp, with four interwoven leather belts. At least one such mat is provided for each section of the pit. The injured are wrapped up in these mats at the place of the accident and lightly bound round with the belting, staves being then passed through the latter and the whole borne to the main heading, where the sufferer is laid on a special iron truck, mounted on flexible

[1] *Zeitschrift für Berg-, Hütten-, und Salinen-Wesen*, 1895, p. 226; *Oesterreichische Zeitschrift für Berg-, und Hütten-Wesen*, 1898, p. 26.

springs, in which he is conveyed to bank. The truck can be slung on the winding-rope or chain in case of need. This appliance has proved highly satisfactory, the injured being conveyed to bank without removal from the truck, and there laid on the ambulance stretcher, whilst still wrapped in the mat.

Before this arrangement was devised the injured had to be shifted several times on the way to the hospital; a different means of conveyance being required in the galleries to that in the shaft, and a third for surface transport. To avoid the pain and probable injury caused by these frequent changings about, Messrs. Knoke & Dressler, of Dresden, made, for the Royal Colliery at Zaukerode, a stretcher which can be telescoped to 60 inches and easily carried through headings and shafts. In headings, the stretcher is first mounted on a suitable truck and shortened as required; and the same also applies to its conveyance through shafts The same stretcher can also be used above ground. It consists of a braced wooden frame with box, adjustable back rest, iron bow feet, telescoping bearer staves, and removable cover of brown canvas, the cost of which is 90 marks (shillings); horse-hair mattress 25 marks (shillings) extra.

The same makers also supply portable stretchers with suspensory appliances. The stretcher is suspended on four double springs attached to arms on the bearing frame, jolting being thereby prevented. It is also suitable for conveyance on ordinary trucks, in which case the suspensory appliance is unscrewed and transferred to the truck. The cost of this stretcher amounts to 170 marks (shillings) for the bearing frame and suspensory appliance; 160 marks (shillings) for the stretcher; 25 marks for the mattress and pillow; 14 marks for a pair of carrying straps; rubber underlay 9 marks.

The prices of this stretcher shown on Plate III., and supplied by the same makers, are as follows:—

Figure	9	25 marks.
„	10	42 „
„	11	38 „
„	12	50 „
„	13	50 „

The Mining Police Regulations (6th April, 1897) of Mährisch-Ostrau prescribe that every colliery must be provided with a rescue station above ground, and as near as possible to the entrance shaft, *i.e.*, a chamber for storing respiratory apparatus for use in irrespirable gases, the necessary electric miners' lamps and goggles, and tarred canvas, sailcloth, or other appliance for the rapid erection of air barriers.

With the consent of the Mining Department, several adjacent collieries may share a station between them, which, in such case, must of course be equally accessible at all times to each.

An official, named by the Mining Department, is entrusted with the supervision of the rescue station; he is also responsible for its proper maintenance, and has to see that the respiratory apparatus, electric lamps, etc., are always kept fit for use.

With regard to the respiratory apparatus, this must be such as can be safely used for at least an hour, and allow the wearer unrestricted freedom of movement. The Walcher-Gärtner pneumatophor and the Neupert apparatus are recognised as fulfilling these requirements. The number of the respiratory apparatus to each rescue station must amount to 5 per cent. of the maximum staff per shift, and the number of men trained in rescue work must be twice as many as there are sets of apparatus. These men must be distributed in a suitable manner in the various shifts.

In order that suitable precautions may be taken on the occurrence of fire-damp explosions or pit fires, and to guard against injurious forgetfulness, the mine manager is obliged to instruct certain men beforehand in the performance of detailed precautions with a view to such contingency, so that they know what they have to do without further orders in case of an accident. Among these duties are the control of the ventilator and the overhauling of any shaft covers that may be at hand.

During the whole time rescue work is being performed, the ventilator must be constantly looked after by an experienced man. An increase in the speed of the fan is characterised as being advisable only in exceptional cases, and it is mentioned that reliable action is of more importance than any increase in the intake current; and that on the other hand an increase in the velocity of the air current may possibly become injurious and a source of danger to the men fleeing from smoke and after-damp.

Other precautions to be taken above ground are: procuring medical assistance as soon as possible; getting the rescue apparatus in readiness; accurate mustering of the escaping miners; giving notice at once to the inspecting officials, as well as to neighbouring pits with a view to obtaining assistance; finally, to prevent curious bystanders from flocking on the premises.

In the first place it should be ascertained whether there are any indications of the existence of fire—which will soon be afforded by the issue of a dark smoke through the ventilator stack. Provided good grounds exist for supposing that fire has broken out, then volunteers should be called to enter the workings as quickly as possible and help any other men who may have been left behind there. If, however, in consequence of the fire being located in the neighbourhood of a presumably fiery goaf, the occurrence of further explo-

sions is feared, or when such explosions have already occurred of such violence and extent as to necessitate the conclusion that no one could have been left alive in the affected section, then attempts at rescue must be abandoned in order that the rescue party may not be uselessly exposed to danger. In such event suitable precautions for extinguishing the fire should be taken immediately.

If, on the other hand, an outbreak of fire does not seem to have occurred, the rescue work, if undertaken with care, can be carried out without danger, by following the ventilating current passing through the seat of the explosion; repairing any brattices, etc., and advancing in the fresh air current to the scene of the accident. To accelerate this work, the rescue station can be divided into two parties, one of them going in advance so far as the respiratory apparatus in use permit, in order to bring any injured or unconscious miners back into the fresh air as quickly as possible, whilst the second party follows and repairs the damaged air conduits. In any case it is advisable to increase the ventilation in the endangered section at the expense of other subdivisions of the current, provided this course does not entail danger to any other part of the workings.

If no reliable reports regarding an apparently violent explosion have come to bank, so that the effect of the explosion affords the sole indication of the necessity for rescue work, the manager, after seeing that all arrangements have been made above ground, must first ascertain whether the winding arrangements are all right and the shaft free from after-damp — which latter may be ascertained by slowly lowering and raising a cage fitted with lighted candles. He should then order the descent of a rescue party fitted with respiratory apparatus, electric lamps and a few safety-lamps (to act as fire-damp indicators), under the command of an official. According to circumstances, the rescue party should

put the respiratory apparatus in use at once, or carry the same for momentary employment in case of need.

The duties of the first rescue party going down are principally:—

1. To ascertain whether any short circuit has been formed between the intake and upcast air shafts, and, if so, prevent same.

2. To appoint suitable men to attend to the signalling on the main levels.

3. To send quickly up to bank any miners found unconscious or injured.

4. To give notice of the accident to miners in other parts of the workings, and instruct them to come out of the pit; and

5. Strengthened by the suitably armed party, which has in the meantime been sent down by the manager, to advance in the fresh-air current towards the scene of the catastrophe, locate same, and send notice to the manager.

Meanwhile the manager has to see that all the necessary materials for rescue and recovery work in the pit, such as boards, canvas, nails, spars, reserve doors, etc., are lowered in sufficient quantities when required. He must organise the relief party, armed with respiratory apparatus and electric lamps, to strengthen the first party sent down. He will receive the reports of the overmen coming up with their subordinates from the unaffected parts of the pit, and see that men possessing requisite local knowledge are stationed at all passage-way crossings to point out the road; and also that a large number of electric and other safety-lamps are lowered and distributed through the pit to light the loading places and the miners' lines of retreat.

The use of rescue apparatus will be successful only when in the hands of properly instructed men. Many experts look upon the aforesaid rescue stations as useful only in the case

of pit fires, but not from explosions. Thus, an editorial in *Glückauf* (1898, No. 15, page 298), says: "In our opinion these rescue stations, though they may be of use in pit fires, are of little value in cases of explosion—at least that is the experience gained in the Ruhr district. Owing to the destruction caused in the headings by an extensive explosion, progress is sufficiently difficult without the hindrance caused by rescue apparatus, and, consequently, rescue parties armed with this apparatus are less likely to arrive on the scene in good time. Furthermore, the men intended to use the apparatus are themselves generally in the pit, and considerable time is therefore wasted before they can be got ready for action. Hence the possibility of rescuing any suffocated miners in this manner is very doubtful. Of far greater importance is it—as emphasised in the Austrian Ordinance—that all the colliery officials should be accurately informed as to what can be done in order to remove the after-damp as quickly as possible after an explosion has occurred; since it is only after this has been done that the rescue parties can make any rapid progress."

In opposition to this view the author may state that, on the occasion of the coal-dust explosion at Anina on 20th October, 1894, where forty-eight lives were sacrificed, thirteen men, who were suffocated by after-damp in a portion of the workings over 2,000 yards away from the seat of the explosion, could undoubtedly have been saved had any proper respiratory apparatus been available. Either the accumulated after-damp could have been easily removed with the assistance of such apparatus; or, in view of the fact that all thirteen men lay in heaps close to the winding shaft, a rescue party could have advanced into the fire-damp direct. Moreover, experience gained at numerous pit fires during the last few decades affords convincing evidence that such rescue stations would frequently have been of very great value.

Unfortunately, at that time, usable respiratory apparatus was lacking.

With regard to the number of respiratory apparatus to be stocked, Mining Councillors Behrens and Mayer expressed the opinion that ten sets are sufficient, and that in fixing the number the difficulty of training twice as many men must be taken into consideration. "It appears more important to have a smaller and reliable rescue staff than a large number of insufficiently-instructed men." In Mayer's opinion at least ten sets of apparatus should be stored in the rescue chamber above ground at each pit, and at least five at each intake shaft, together with a suitable number stored in underground rescue stations near the most dangerous parts of the workings.

(*b*) *Underground Rescue Stations.*

As these stations have not as yet been very largely installed, it will be sufficient to mention a few instances, occurring in pit fires, which raise the question whether refuge places, provided with compressed air and other remedial appliances, such as respiratory apparatus, electric lamps, refreshments, drinking water, etc., could not be arranged at certain places in coal pits. As far back as 1862, on the occasion of an accident, involving the loss of many lives, at Leoben, through the smoke fumes from a burning shed at the pit mouth finding their way down into the workings, a portion of the men saved themselves by erecting a barrier to keep back the advancing fumes. Again at the Herminegild shaft fire in 1896, several men, who were better protected from smoke fumes in the side passages, were able to make use of compressed air for respiration, managed to escape; and similar observations were recorded at the fire in the Kleophas pit (1896). Mining Councillor Mayer proposed, after the Herminegild shaft fire, that such refuges,

ordinarily left open, should be closed by doors constructed for the purpose, fitted with glazed windows and kept in reserve, and then protected from the influx of smoke fumes by introducing a supply of compressed air. Of course, these precautions would necessitate the men being thoroughly instructed beforehand; but in such case many unauthorised and useless attempts at rescuing the fleeing miners would be prevented.

VII. SPONTANEOUS IGNITION OF COAL IN BULK.

According to Ainsworth, the principal causes of spontaneous ignition in coal are: friction, chemical action and pressure. The tendency of coal to become hot is due to absorption of solar heat and atmospheric oxygen. The carbon of coal being a bad conductor of heat, it therefore retains the greater part of the heat absorbed. In the case of damp coal, heat is developed in larger quantity than when dry, and the moisture is converted into vapour, this sweating being increased by the moisture. It may therefore be taken for granted that in large damp heaps of coal a great volume of heat can be developed under these favourable conditions, particularly in the bottom of the mass. Small coal is more active in this respect than large blocks, the heat being unable to escape as quickly as it is developed, owing to the absence of air circulation, and it therefore accumulates, the temperature increasing in proportion to the depth of the mass. Pressure is another cause of spontaneous combustion; for though in itself it does not produce any great amount of heat, it favours its development and accumulation.

The most important cause of all, however, is chemical reaction. The heat thus developed seizes upon the elements for which it has the greatest affinity, iron pyrites being decomposed into iron and sulphur, and the latter oxidised. Naturally the first product of spontaneous ignition is steam,

the other volatile gases being liberated according to their volatility and density. The latter quality increases and volatility diminishes the nearer we get to the bottom of the mass, until hot coal, giving off black smoke consisting of carbon, carbon dioxide and other gases, is reached. The liberation of gas goes on until nothing but coke is left.

To prevent spontaneous combustion, wooden shafts are oftentimes put in while the coal is being piled on the heaps. According to Muck, these shafts, in the ordinary loosely constructed form, are actually harmful, as they facilitate the circulation of air, and consequently oxygen absorption, in the middle of the heap. And in fact it has been found in cases of fire that, where these shafts have been used in inflammable coal, the outbreak always occurred at the contact surfaces of the wood and coal, *i.e.*, where, during the drying of the coal, the air that has been impoverished in oxygen is replaced by a fresh supply.

In England the question of spontaneous ignition in bulk has become very grave, owing to the serious losses and dangers arising from the heating of coal heaps containing 2,000 tons and upwards, especially in the carrying trade and during prolonged storage; the losses of life and property in the year 1875 being so great that a Royal Commission was appointed to establish suitable precautions against accidents of this kind. Nevertheless the deliberations were attended with so little success that during the nine years next ensuing no less than fifty-seven coal vessels were lost in consequence of their cargo taking fire. Although the accidents from this cause at sea are of a far worse nature than when a coal store takes fire on land, the latter is always attended with considerable loss, even when the whole is not destroyed by fire and the coal is merely dissipated by spontaneous heating.

At the conclusion of his paper on the enormous losses occasioned in England by the spontaneous ignition of coal

during storage, Prof. V. B. Lewes stated that spontaneous heating is of rare occurrence in newly got coal unless piled up in unusually high heaps, since, even though coal, stored immediately in the open air, absorbs oxygen, the access of air to the individual blocks prevents any considerable rise in the temperature when the heaps are small. When, however, in consequence of frequent handling, the lump coal is broken into dust (*e.g.*, in loading on board ship), fresh surfaces are constantly exposed to the air, the result being a rapid absorption of oxygen and corresponding accession of temperature.

Reviewing the possible causes of spontaneous ignition in coal, the following points, as influencing rapid heating, are worthy of mention :—

1. Nature of the coal, and principally the degree of moisture present, since the larger this proportion the greater the absorptive capacity of the coal towards oxygen and the more rapid the attendant development of heat.

2. The size of the lumps—whether dust, nuts, cobbles or large lumps—is very important, the smaller sizes heating more readily than the larger.

3. Coals should not be shipped or thrown up in heaps during wet weather. Although the external moisture from rain or snow does no damage at first, it is gradually absorbed into the heaps, which it penetrates, and by degrees increases the affinity of the coal for oxygen.

4. Ventilation is injurious unless it can be thoroughly effected by passing cold air through the heap in all directions.

5. As, however, any increase of temperature in stored coal heaps is injurious, outbreaks of fire are in many cases traceable to direct contact of the coal with steam-pipes, furnace flues, or warm walls.

Accordingly, under no circumstances should a steam-pipe or flue be placed near the stored coal; and the latter should

be at least twenty feet away from any boiler, fire or retort. No coal should be stored in a heap or loaded on shipboard until a full month has elapsed since it was raised. Precautions should be taken to minimise the breakage of coal during loading; no smalls or dust coal should be piled up in large heaps; and 70-80 inches should be the maximum height of any coal heap.

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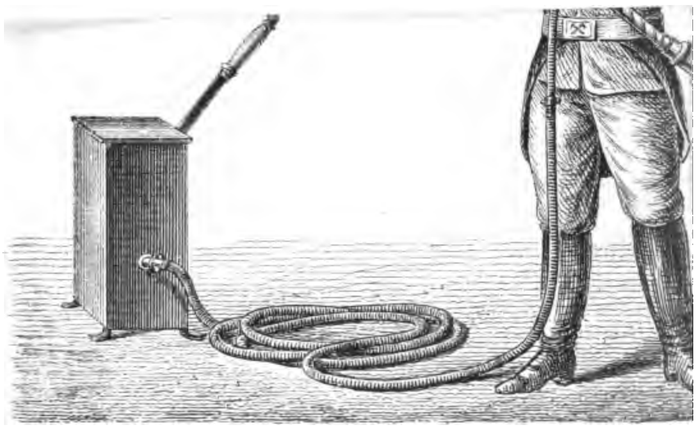

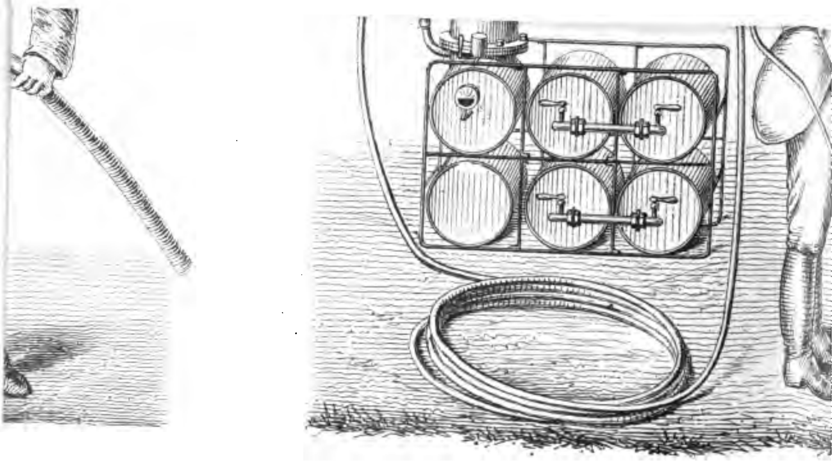

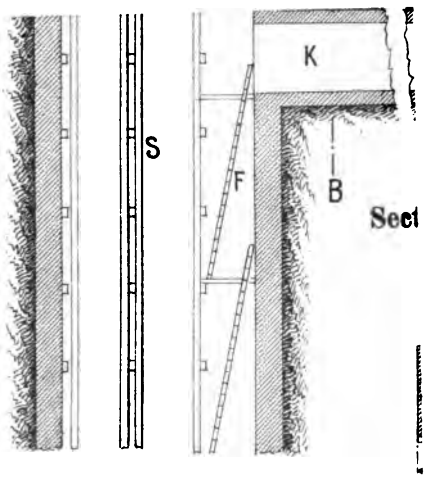

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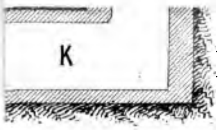

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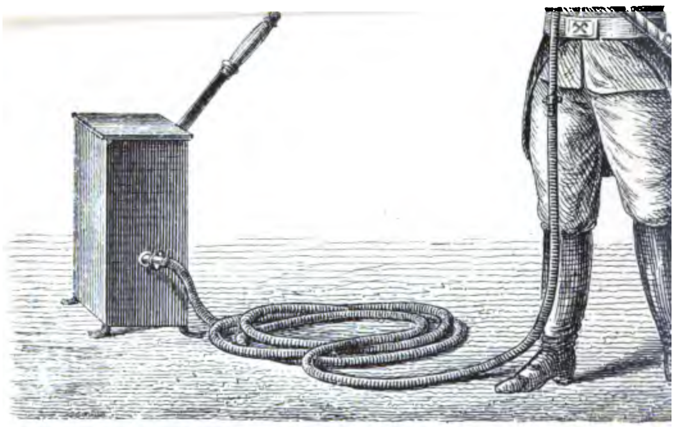

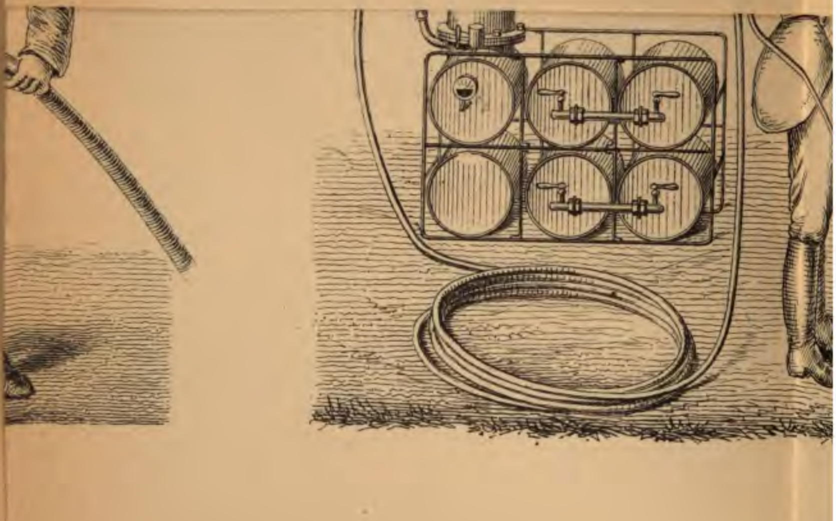

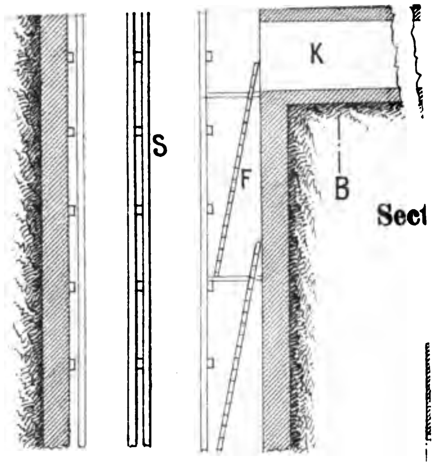

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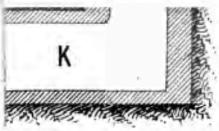

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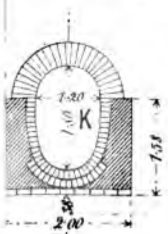

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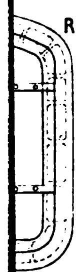

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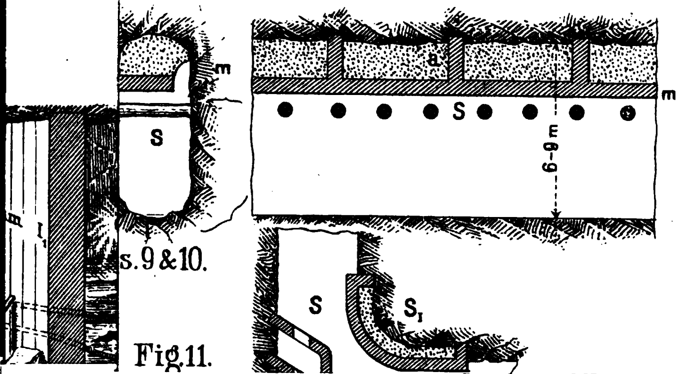

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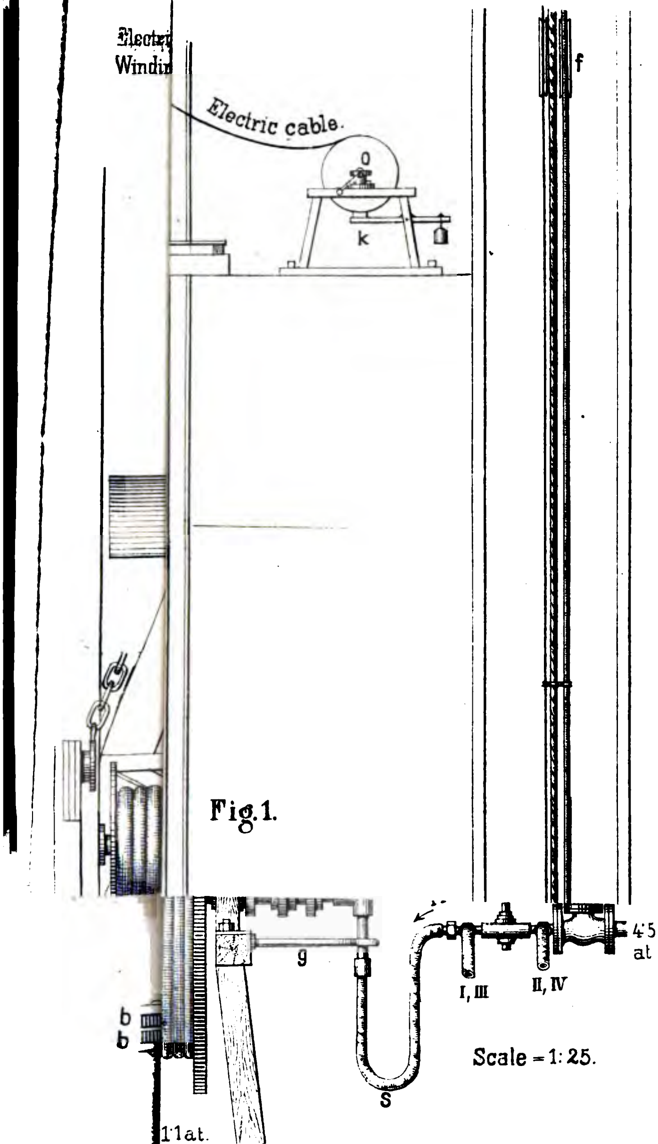
Fig.11.

h. Mayer System.



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